PROCEEDINGS

OF THE

ROYAL PHILOSOPHICAL SOCIETY

OF GLASGOW

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PLATES.

PROCEEDINGS
OF THE
ROYAL PHILOSOPHICAL SOCIETY
OF GLASGOW.

SESSION 1904-1905.

Methods of Artificial Respiration. By E. A. SCHÄFER, LL.D., F.R.S., Professor of Physiology in the University of Edinburgh.

[Notes of a Lecture delivered before the Society on the 2nd November, 1904.]

OBJECTS of both natural and artificial respiration.

Natural respiration: How effected.

Self regulating nervous mechanism: How acting.

Amount of air exchange in natural respiration: How ascertained: Spirometer. The kind of spirometer employed is that described by Marcet (see Figs. 1 and 2). Estimates of various authors vary from 250 cc. to 600 cc. per *respiration.*

FIG. 1.—Marcet's spirometer fitted with water valves, and mask for testing methods of artificial respiration.

But as the number of respirations per minute varies in different individuals (6 to 24 are extremes in health), it is more important to know the amount of exchange per *minute*.

The amount per respiration will, roughly speaking, vary inversely as the number per minute.

Vierordt got 446 cc. per respiration with a frequency of 11.9 = 5,307 cc. per minute.

Marcet got 250 cc. per respiration with a frequency of 16 = 4,000 cc. per minute.

Schäfer got 450 cc. per respiration with a frequency of 13 = 5,850 cc. per minute.

It is always necessary in the first instance to ascertain the air exchange and the number of natural respirations per minute in any individual who is to be the subject of experiment on the value of artificial respiration methods.

METHODS OF ARTIFICIAL RESPIRATION AT PRESENT EMPLOYED.[1]

SILVESTER METHOD. So-called "natural" method; consists of

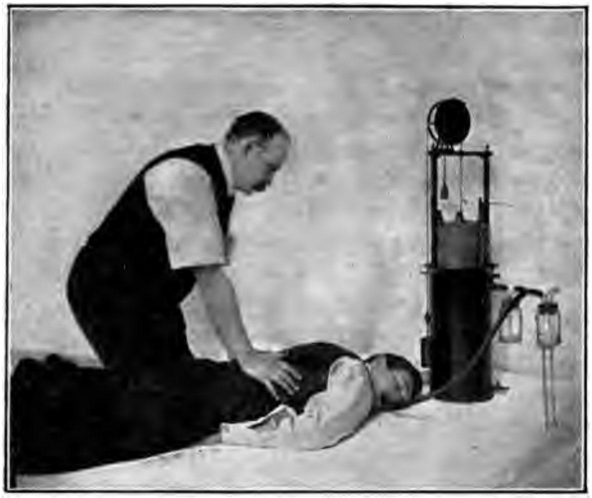

FIG. 2.—Methods of using spirometer to test the efficiency of artificial respiration. The prone pressure method is being employed, and a mouthpiece is being used instead of the mask shown in Fig. 1. When this is done it is necessary to occlude the nostrils.

traction of arms alternating with lateral pressure on chest; prone position throughout.

[1] For full description, see Appendix.

MARSHALL HALL METHOD. Consists in rolling patient over from lateral to prone position, with pressure on back when in prone position.[1]

HOWARD METHOD. Consists of intermittent pressure over lower ribs with patient in supine position.

AMERICAN METHOD. (Kedzie & Baker). Pressure upon the lower ribs with patient in prone position, alternated with raising the chest off the ground; the operator standing over the patient.

The result of testing these methods with the spirometer is as follows:—[2]

1. NATURAL RESPIRATION of subject of experiment.

(*a*) SUPINE POSITION. Rate, 13.

Amount expired per minute, 6,460 cc.; per respiration, 489 cc.

(*b*) PRONE POSITION. Rate, 12·5.

Amount expired per minute, 5,240 cc.; per respiration, 422 cc.

Average for supine and prone positions—per minute, 5,850 cc.; per respiration, 450 cc.[3]

2. SILVESTER. Rate, 12·8.

Amount expired per minute, 2,280 cc.; per respiration, 178 cc.

3. MARSHALL HALL. Rate, 13.

Amount expired per minute, 3,300 cc.; per respiration, 254 cc.

4. HOWARD. Rate, 13·6.

Amount expired per minute, 4,020 cc.; per respiration, 295 cc.

Of these three methods the Howard gave the nearest approach to the normal amount per minute, but still fell short by more than 1,000 cc. Probably with greater rate or more forcible pressure a larger amount could be exchanged by the Howard method, but this is not the case with the Silvester or Marshall Hall, the complications of which occupy too much time.

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[1] To this Dr Bowles adds the raising of one arm over the head, when the body is in the lateral position.

[2] The numbers here given and the exact method used for obtaining them will be found in a paper read before the Royal Society of Edinburgh, on Dec. 21, 1903, and published in the *Proceedings*, vol. xxv., p. 39.

[3] Or, per minute, 360 cub. in.; per respiration, 28 cub. in.

All the above methods are attended by special inconveniences and dangers as follows:—

SILVESTER METHOD. Great labour. Supine position causes tongue to fall back, and mucus to accumulate in throat and air passages. Inefficiency. This is not only shown by the spirometer readings but also by the fact that the subject finds it *necessary* to breathe after a very short time; his respiratory exchanges cannot be maintained by it. The fact that the natural movement of the ribs is imitated has led its being designated the "natural" method. But the imitation is imperfect and inefficient, as the above facts indicate. *Nevertheless this is the only method recommended by the Royal Humane Society.*

MARSHALL HALL METHOD. Considerable labour, but less than Silvester. Avoids the supine position and allows tongue to come forward and mucus to escape. But is complicated and requires time so that it is difficult to execute fast enough without injury to patient. The amount exchanged is therefore insufficient, and as with Silvester method the subject feels the necessity of breathing. *Nevertheless this is put in the first place by the National Lifeboat Institution; the Silvester method being also recommended.*

HOWARD'S METHOD. Is fairly efficient and simple, but as described by Howard is laborious. The dangers are (*a*) those inseparable from the supine position, such as falling back of tongue, accumulation of mucus, etc., in throat and air passages.

(*b*) Breaking of ribs from excessive or too sudden pressure. This has been known to happen (also with the Silvester method).

(*c*) Rupture of liver (which is greatly swollen in asphyxia). This has been found *post mortem* (also with Silvester method). The Howard method is probably more often used by medical men than either the Silvester or the Marshall Hall. All three are taught by the instructors of the Life Saving Society.

AMERICAN METHOD. The raising of the body of the patient is entirely unnecessary and fatiguing to the operator. Otherwise the method avoids most of the dangers of the other three.

PRONE PRESSURE METHOD.[1] In the course of experiments conducted on behalf of a Committee of the Royal Medical and Chirurgical Society an attempt was made to apply the traction or Silvester method in the prone position—to obviate the dangers

[1] This method was described in a paper read before the Royal Medical and Chirurgical Society of London on December 8, 1903, and published in the *Transactions* of that Society (vol. 87). See also Appendix to this paper.

of the supine position. This was found, however, to be still more laborious and even less efficient than in the supine position. It then suggested itself that perhaps a modification of the Howard or pressure method might be used, but in the prone position, in which case all its special dangers would be avoided. The result of testing this method by the spirometer was as follows :—

5. PRONE PRESSURE. Rate per minute, 13; amount per minute, 6,760 cc.; per respiration, 520.

The experiments were conducted in all respects in the same manner as with the others (see p. 5) and upon the same subject. The pressure is applied over the lowest part of the thorax. During the performance of artificial respiration by this method there is no necessity to breathe, the method being fully efficient to maintain the respiratory exchange. It can be kept up for an hour or more without the least fatigue to the operator or inconvenience to the subject. The muscular exertion necessary is simply that required to sway the body (in a kneeling position) backwards and forwards slowly, about 12 times a minute so that the weight of the upper part of the operator's body—amounting to about half his full weight—is brought to bear on the hands, which are placed flat over the floating ribs. The pressure is transmitted and diffused over the whole abdomen and thorax. There is no risk to liver and should be none to ribs—but with any method care must be exercised in old subjects, in which the ribs are brittle.

The method has special advantages in cases of drowning. It is simple enough to be understood and applied by any one—*even single handed.* It can be employed *anywhere.* No preliminary manipulation is necessary. The mouth and air passages become emptied of water and mucus and the tongue falls forward, automatically. There is no appreciable fatigue involved, and the efficiency is greater than that of any other method. Lastly, by its very nature it tends to stimulate the natural respiratory process, since any active diminution in size of the lungs has the effect of itself tending to produce a natural inspiration. For all these reasons it should be adopted without hesitation by all who are interested in the saving of life. It is worse than useless to go on teaching a number of complicated methods which are not even efficient for their purpose. In a case of drowning there is no time to try first one and then another method. Every minute, every second, is of consequence. If breathing has ceased, even for 5 minutes, it is probably impossible to effect re-

covery at all. Not an instant therefore must be wasted in removing clothing, in applying warmth or in any of the other procedures which are still recommended as preliminaries by life-saving societies. All these give away the patient's only chance, which is to get air into and out of the lungs as soon and as actively as possible. The method here advocated is already being taught in first aid classes organised under the auspices of the L.C.C., and the evidence of medical men who are practically acquainted with the difficulty of carrying out the current methods of artificial respiration show that this method—which is at once ready, simple and efficient—is likely to be of real service in such cases of emergency as require artificial respiration. Not only in drowning is the method applicable but in all cases in which the necessity arises for the artificial maintenance of air exchange in the lungs; as may occur from accidents of various kinds—such as contact with live wires; poisoning by illuminating or power gas; mining accidents; poisoning with chloroform or morphia; and shock resulting from blows and injuries to the head. It may be possible to effect recovery in any and all of these kinds of accidents by the immediate application of an artificial respiration method of proved efficiency. But it must be borne in mind that the application must be immediate—in a very few minutes the patient may have passed beyond recovery. It is therefore obviously of importance that every one should know how to apply the only remedy which is applicable in these cases, viz., artificial respiration. And, since we have in this method a means of carrying on artificial respiration, which is simple, easy of application, which requires no special strength or skill, and no technical knowledge, and is moreover completely efficient, the method ought to be taught not only to a few selected members of the community, such as coastguardmen, humane society men, policemen, and the members of first aid classes, but to every school child. If this were done the life of many a man, who has to be pronounced dead by the doctor when he arrives upon the scene, would be saved.

APPENDIX.

DESCRIPTION OF THE METHODS OF ARTIFICIAL RESPIRATION DEALT WITH IN THE ABOVE LECTURE.

1. Dr H. R. Silvester's Method. (From the instructions issued by the Royal Humane Society for restoring the apparently dead from drowning, suffocation, or narcotic poisoning).

Place the patient on his back on a flat surface inclined a little from the feet upwards; raise or support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades. Remove all tight clothing about the neck and chest.

Cleanse the mouth and nostrils; open the mouth; draw forward the patient's tongue, and keep it forward; an elastic band over the tongue and under the chin will answer this purpose.

Place yourself at the head of the patient, grasp his arms, raise them upwards by the sides of his head, stretch them steadily but gently upwards, for two seconds. Immediately turn down the patient's arms, and press them—or your own hands—gently against the sides of his chest, for two seconds.

Repeat these measures alternately, deliberately, and perseveringly, fifteen times in a minute, until a spontaneous effort to respire be perceived.

2. Marshall Hall's method. (From the directions for restoring the apparently drowned, issued by the Royal National Lifeboat Institution).

Place the patient on the floor or ground with the face downwards, and one of the arms under the forehead, in which position all fluids will more readily escape by the mouth, and the tongue itself will fall forward, leaving the entrance into the wind-pipe free. Assist this operation by wiping and cleaning the mouth. Raise and support the chest well on a folded coat or other article of dress.

Turn the body very gently on the side and a little beyond, and then briskly on the face back again, repeating these measures cautiously, efficiently, and perseveringly, about fifteen times in the minute, or once every four or five seconds, occasionally varying the side.

On each occasion that the body is replaced on the face, make uniform but efficient pressure with brisk movement, on the back between and below the shoulder blades, renewing the pressure immediately before turning the body on the side.

During the whole of the operations let one person attend solely to the movements of the head and of the arm placed under it.

3. Howard's method. ("How to restore the drowned," reprinted from a note by Dr B. Howard, January 14, 1869.)

Instantly turn patient downwards, with a large firm roll of clothing under stomach and chest. Place one of his arms under his forehead, so as to keep his mouth off the ground. Press with all your weight two or three times, for four or five seconds each time, upon patient's back, so that the water is pressed out of lungs and stomach, and drains freely out of mouth. Then quickly turn patient face upwards, with roll of clothing under back, just below the shoulder-blades, and make the head hang back as low as possible. Place patient's hands above his head. Kneel with patient's hips between your knees, and fix your elbows firmly against your hips. Now, grasping lower part of patient's naked chest, squeeze his two sides together, pressing gradually forward with all your weight, for about three seconds, until your mouth is nearly over mouth of patient, then with a push, suddenly jerk yourself back.

Rest about three seconds; then begin again, repeating these bellows-blowing movements with perfect regularity, about eight or ten times a minute, for at least one hour, or until patient breathes naturally.

4. Kedzie and Barker's method. (From "Treatment of the drowned suffocated or electrically shocked," leaflet issued by the State Board of Health of Michigan.)

Remove all obstructions to breathing. Instantly loosen or cut apart all neck or waist bands.

Turn the patient on his face, with the head downhill; stand astride the hips with your face towards his head, and, locking your fingers together under his belly, raise the body as high as you can without lifting the forehead off the ground, and give the body a smart jerk to remove mucus from the throat and water from the wind-pipe. Hold the body suspended long enough to slowly count one, two, three, four, five, repeating the jerk more

gently two or three times. Then, keeping the patient face downward, and maintaining all the while your position astride the body, grasp the points of the shoulders by the clothing, or if the body is naked, thrust your fingers into the armpits, clasping your thumbs over the points of the shoulders, and raise the chest as high as you can without lifting the head quite off the ground, and hold it long enough to slowly count one, two, three.

Replace him on the ground, with his forehead on his flexed arm, the neck straightened out and the mouth and nose free. Place your elbows against your knees and your hands upon the sides of his chest over the lower ribs, and press downward and inward with increasing force long enough to slowly count one, two. Then suddenly let go, grasp the shoulders as before and raise the chest, then press on the ribs, etc.

These alternate movements should be repeated ten to fifteen times a minute for an hour at least, unless breathing is restored sooner.

5. Prone-pressure method. ("Instructions for the treatment of the apparently drowned," from the paper in the Medico-Chirurgical Transactions, vol. 87, already referred to.)

Immediately on removal from the water, place the patient face downwards on the ground with a folded coat under the lower part of the chest. Not a moment must be lost in removing clothing. *If respiration has ceased, artificial respiration is to be commenced at once: every instant of delay is serious.*

To effect artificial respiration put yourself athwart, or on one side of the patient's body in a kneeling posture and facing his head (see figure). Place your hands flat over the lower part of the back (on the lowest ribs), one on each side, and gradually throw the weight of your body forward on to them so as to produce firm pressure—which must not be violent—upon the patient's chest. By this means the air (and water, if there is any) is driven out of the patient's lungs. Immediately thereafter raise your body slowly so as to remove the pressure, but leaving your hands in position. Repeat this forward and backward movement (pressure and relaxation of pressure), every four or five seconds. In other words, sway your body slowly forwards and backwards upon your arms twelve to fifteen times a minute, without any marked pause between the movements. This course must be pursued for at least half an hour, or until the natural respirations

are resumed. If they are resumed and, as sometimes happens, again tend to fail, the process of artificial respiration must be again resorted to as before.

Whilst one person is carrying out artificial respiration in this way, others may, if there be opportunity, busy themselves with

FIG. 3. Illustrating the method to be adopted for effecting artificial respiration in cases of drowning.

applying hot flannels to the body and limbs, and hot bottles to the feet; but no attempt should be made to remove the wet clothing or to give any restoratives by the mouth until natural breathing has recommenced.

A Theory of Education. By JAMES COLVILLE, M.A., D.Sc.

Read before the Society, 14th December, 1904.

THE theorist is apt to be misunderstood and in consequence depreciated. His theorising is held to imply, either a pretence of superior wisdom, or the aim of the visionary in contrast to that of the man of practical commonsense. It is necessary at the outset to disclaim both of these views. The "theōros" in Greek was the onlooker, who is proverbially said to see the best of the game. The "theōroi" were state-ambassadors sent to the Delphic oracle or to the great national games, and, as such, held in the highest honour. Theorising is a useful, and, at the worst, a harmless, contrivance to present a reasoned-out scheme, showing the general and essential principles underlying a series of related facts or phenomena. And, after all, practice asserts itself, for here, as elsewhere in real life, the virtue lies in the application.

It was fitting that the Renaissance should witness the dawn of modern education. Bacon, its brilliant occidental star, was ever an educationist of most pregnant wit. The strength of his philosophy is his method,[1] a scheme of education which should at once inspire and direct the searcher after knowledge. His temple of Science is too vast for the ordinary beholder, but in the "Essays" we have the student in the making, thinking aloud practical wisdom that "comes home to men's business and

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NOTE :—Bacon's "Essays" will always rank high among the world's classics. The first edition, of ten Essays, appeared in 1597; the second, of thirty-eight, was published in 1612. The "newly enlarged" edition, as we have it, is dated 1625. The two-volume edition of Dr Edwin A. Abbott, (1876) is admirably equipped with every aid the student is likely to require. Whately's (1864) is annotated very fully in a vein of homely common-sense.

[1] A writer in "Blackwood" (Jan. 1905), discussing the burning question of "Compulsory Greek," has these apposite remarks :—"The duty of the Universities is to teach *methods* and *methods alone.* We cannot ask a boy of twenty to achieve a piece of lasting or original work. But we can expect his mind to be so well trained that, when the time comes with ripened experience and broader outlook, he shall perform something which his contemporaries will not despise, and method alone will make this performance possible."

bosoms." He uses the word Essay in its early sense of "attempts," to set a-thinking and invite further remark. To Prince Henry he says, "My hope is, they may be as graynes of salte, that will rather give you an appetite, then offend you with satiety . . . breif notts, sett downe rather significantlye" (in posse) "than curiously" (in esse). Bacon, therefore, in virtue of his suggestiveness, his open mind, his unquenchable thirst for truth, is eminently fitted to guide where the contemplative and the active life run together. As he was on the flowing tide of the Renaissance, so we too are at a point when a fresh step forward must be made. It is too late in the day for any new theory bearing on the facts of human experience. But the wisdom of Bacon can never grow old.

Many wise sayings are scattered throughout the Essays which are precious for the culture of the intellect. They are most frequent in "Studies, Truth, Custom and Education, Discourse and Seeming Wise." He has been fortunate in his commentators, Archbishop Whately and Dr. Edwin A. Abbott, who unite logical acumen and graceful scholarship with wide teaching experience. In their setting of the Essays one cannot fail to see the full worth of the gems. The classical passage in this educational connection occurs in "Studies":—"Reading maketh a full man; conference a ready man; writing an exact man." It is comprehensive enough to embrace a whole scheme of a liberal education. Bacon had the poet's eye though without the fine frenzy or the mechanic faculty of verse. No author delights more in large thoughts. In "Truth" there is a splendid expatiation of the aphorism in "Studies." Here we have the same threefold clew to thread the maze of Science—"Truth which only doth judge itself" (right reason) "teacheth that the inquiry of truth (which is the love-making or wooing of it), the knowledge of truth (which is the presence of it), and the belief of truth (which is the enjoying of it) is the sovran good of human nature. The first creature of God was the light of the sense; the last was the light of reason; and His Sabbath-work, ever since, is the illumination of His spirit." Thus have we the fulness of the inquiry by reading and observation, the exactness of knowledge by writing and reflection, and the readiness of belief in the use of it for the delight or edification of our fellows.

Bacon's fulness as the aim of reading is simply the acquisition of knowledge from books or from the observation of men and

things. But this empirical and observational stage implies a preliminary training in the art of reading and observing. Technique must precede effective production. This mechanical practice, like learning to walk, the meaning of which is a mystery to the child, supplies a faculty, a mould wherein to cast individual activities to the best advantage. Every form of human energy has its own language as at once the basis of production and its interpretation, whereby out of the Babel of confusion may spring the unity of a mutual understanding. As man is essentially a social animal, learning to read should go exactly on the lines of learning to speak. Imitation, the delight in doing what the grown-up does, will give vitality to what must otherwise seem but arbitrary symbols. At this stage the helplessness of the child is the secret of its extreme docility. "Custom," as Bacon says "is most perfect when it beginneth in young years: this we call education, which is in effect but an early custom." Later on, when character begins to show, it will be otherwise. "Youth has an inherent contempt for the authority of the aged to the end all may gain wisdom at their peril," which is nothing but the assertion of individual interest. Were education to remain at the merely imitative stage we should rise no higher than the lower animals. In them there is no reflection, no philosophising, because their intellect in itself cannot be cultivated without the mutual bond of language. Thus even the animals that have been longest in contact with man do not of their own accord imitate his actions. Imitation must remain as a stand-by till reason is developed, in the form of repetition and iteration. This is the catechism (Gr. *Katechein*, to din into one's ears) or early stage in the history of all education, when precepts and formulæ were memorised and inculcated, or trodden under the heels of unmeaning discipline. James Melville, the Reformer, says of his early instruction on this method, "The treuthe was, my ingyne and memorie war guid aneuche bot my judgment and understanding war as yet smored" (smothered) "and dark, sa that the thing quhilk I gat was mair be rat". (rote) "ryme nor knowledge." Of such methods Bacon has well said, "It needs great perfection if the practice be harder than the use."

When we turn to the matter read, while as yet facility is everything, quantity is to be considered before quality, since taste, or the appreciation of language for its own sake, is as yet in embryo. We must not, however, rate the reading appetite of

the very young too high, as it may be due only to laziness or a lively sense of favours parental to come. In one of Bacon's Antitheta or suggestive half-truths he says what may be true of such reading, "Contemplation is but a specious sloth." The concrete, too, must precede the abstract, for the senses, that is, the observation, are natural tools, while reflection is not. The school-books of our forefathers erred in this direction in their didactic insistence on the psalm, the hymn, and the improving moral tale. Now-a-days we cannot have too much of the naïve nursery rhyme, adventure, biography, the charming incongruities of fable and fairyland. As environment only is inherited, not the intellectual plane of the parent, human feelings, situations, and actions are intelligible to the immature mind. It is doubtful if mere description, without a strong human element, will tell with the very young. The appreciation of natural scenery is purely the artificial product of education. The natural man is indifferent to it. Burns and Wordsworth, because with them the human situation overshadows Nature, will succeed, as matter for youthful reading, where Byron and Coleridge fail.

Bacon would assuredly include observation of things as well as of a printed page in his demand for fulness, or the garnering of the facts of experience. Learning to read print, however, is not a rational exercise any more than the mastery of notes and scales in music or the jugglery with vowels and suffixes in accidence. There is somewhere a place for faith and authority even in this scientific age. But observation, to be worthy of the name, implies considerations of time, place, colour, form,—all in an approach to logical sequence. There is a rudimentary and often very exact observation on the part of animals and of the natural man, but only where questions of food, danger, or the society of their kind are concerned. What we call an observant child is felt to be abnormal. And here it is well to remark that what is taught under the specious name of Nature Knowledge may easily be introduced too soon in the curriculum. The humble object-lesson was a safer medium. Here we could always proceed from the known to the unknown, and this in presence of the concrete. For continuity is an essential to all effective brain action. We cannot think in fits and starts. Thus the half-educated have great difficulty in seeing humour, the essence of which is surprise and incongruity. Besides, we are here dealing with handy material, as in reading

from the printed page; but, unless the classroom is the garden, the field, or the forest, the study of things becomes only that of words. Much may be made of a twig, a flower, a leaf, a feather, or an egg, but only after some command of reason and intelligence has been acquired along with some personal contact with the life of the fields.

Education really begins with the awakening of the reasoning powers. Before this we have merely the formal walk in the grooves of imitation and habit. The accumulation of facts through reading and observation, is not knowledge until these come under the influence of the rational or disciplinary process, and be pursued as a means to an end. Bacon says, "All true knowledge consists in knowing the laws and causes of things; mastering these we shall be able to construct, for all knowledge should result in invention." He tells us of his own revolt, at the age of twelve, against scholastic formalism:—"I possessed an earnestness of research; and had noted the unfruitfulness of philosophy which was only strong for disputes and contentions but barren of works for the benefit of life and of man." Without ordered reason man would be lost amid the mazes of the accumulations of sense perceptions. Here let me quote one of those analogies with which Bacon, as was the manner of the Great Teacher, illuminates his path, "Travel in the younger sort is a part of education; in the elder a part of experience. He that travelleth into a country before he hath some entrance into the language goeth to school" (an elementary one) "and not to travel. . . . If you will have a young man to put his travel into a little room and in short time to gather much, this you must do: first, as was said, he must have some entrance into the language; then he must have such a servant or tutor as knoweth the country" (a teacher, that is); "let him carry with him also some card or book describing the country where he travels which will be a good key to his inquiry; let him keep also a diary ('writing an exact man;') let him not stay long in one city or town, more or less as the place deserveth, but not long."

Bacon was quick to see resemblances in things, and this gives his reflections a poetical charm, often happy and always suggestive. "Before logicians use their art," he says, "they ought to imitate the bees gathering stores of flowers, to transmute what they have collected into honey." The formative reason has always the highest place with him. "Read not to contradict and

confute" (as in the old-time Grammar School and College), "nor to believe and take for granted" (as in the Elementary School), "nor to find talk and discourse" (as in society), "but to weigh and consider." The bad ways of the old formalism, as Whately puts it, were hasty, careless, scanty observation, and a want of copious, patient experiment. The most accurate reasoning in form is of no avail unless based on sound facts. Bacon's method was more than a mere accumulated knowledge of facts, extensive but crude. All acquaintance with facts is unprofitable to one whose mind is not trained to read rightly the volume of Nature and the human transactions spread out before him. The fruit Bacon desiderated for his countrymen was long in maturing, but it was the rise of Industrialism and modern complex needs that gave us our scientific triumphs. The tedious evolution of State and Church politics had, for three centuries, to pave the way.

The fulness which comes of reading and observation is either real or spurious. The object legitimately aimed at is mental growth, the creation of a thinking organism that at once accumulates and turns its gains to account in fresh acquisitions. The analogy with the body is significant. Appetite is paralleled by curiosity or the desire for knowledge, nutrition by assimilation with previous acquisitions, volition by the practical application of new faculties of thought and character. The condition precedent to all is interest, the root of sympathy between the learner and what he is learning. There is a crude or elementary stage when obedience is in keeping with the excess of docility over character. But the will produces the understanding and with the emergence of choice comes the assertion of personality. "Nature," says Bacon, "is often hidden, sometimes overcome, seldom extinguished. . . . Men's thoughts are much according to their inclinations." Hamlet says, "There's nothing good or ill but thinking will make it so." The mind of youth, however, is susceptible to good impressions, and of these none are so lasting and so fruitful as those imprinted by a simple, earnest, and unaffected love of knowledge in the teacher. His successes of the intellectual kind are in the best extremely doubtful, for, after all, self-education is alone effective for the pulling down of the strongholds of ignorance; but high character in the teacher invariably tells. Whately wisely remarks, "Education resembles the grafting of a tree in that there must be some affinity between the stock and the graft. Even so the new nature superinduced

by education must always retain some relation to the original one, though differing in most important points." This is as true of the acquisition of knowledge as of the formation of character. All things are not possible for all, and, if possible, not expedient. You cannot make a silk purse out of a sow's ear, it is more useful to the sow as it is. And therefore the teacher may triumph here too in directing intellectual tastes into congenial grooves. His skill must consist, not in imposing the uncongenial, because of the value he himself puts upon it, but in discovering the kind of mental food which can be most effectively assimilated. If the teacher were wise enough to work on the line nature prescribes, which is always that of least resistance, and remember that minds as well as backs are made for their appropriate burdens, there would be fewer hopeless dullards. On his side and working for him there would always be the gratified appetite, and with it that measure of fulness which means satisfaction. In the Antitheta we read "No pleasures are in accordance with nature save those that never breed satiety."

In this disciplinary stage of learning, through subjection to the control of reason, three classes of minds are to be considered—the precocious, the seeming wise, as Bacon calls the victims of cram, and the seeming ignorant, but in reality only not able to show off their knowledge to advantage. Of the first type Bacon says, "There be some have an over early ripeness in their years, which fadeth betimes." Even the ordinary observer has remarked that in the application of early training to real life, slow and steady wins the race. In fruits and vegetables the late variety may be as good as the early. As Whately puts it, "There is nothing less promising than, in early youth, a certain full-formed, settled, and, as it may be called, adult character. A lad who has, to a degree that excites wonder and admiration, the character and demeanour of an intelligent man of mature age, will probably be that, and nothing more, all his life, and will cease accordingly to be anything remarkable, because it was the precocity alone that ever made him so." The second class is treated in the essay, "Of Seeming Wise." Here Bacon has in his mind the Sir Oracle of Shakespeare, the empty formalist. Cowper in Conversation sketches him:—

> "His wit invites you, by his looks, to come,
> But when you knock it never is at home."

The atmosphere of the schoolroom is unfavourable to this im-

postor, but many pretentious methods tend to produce the crammed type of the seeming wise. It results from an appetite for accumulation without the power of rapid or, indeed, of any, assimilation. It is engendered out of mechanical methods of teaching to save time and trouble, an excess of docility, and no little mental laziness on the part of the pupil. To take for granted is ever so much easier than to weigh and consider. Some teachers see virtue in those docile, well-drilled marvels of receptivity. A farmer's wife was overheard scolding a servant for some well-meant but mis-directed effort, to whose apologetic remark that he thought so-and-so, she tartly replied—"You had no business to think," a remark which characterised the attitude of excessive deference to authority that produced generations of devout formalists in Scotland, crammed with the neat tabloids of the Shorter Catechism. The repetition of the Decalogue never kept any one out of the hands of the police. Bacon puts "man's chief end" otherwise—"Merit and good works is the end of man's motion" (endeavours); "conscience" (consciousness) "of the same is the accomplishment of man's rest." The third class, the seeming ignorant or the not so ignorant as they seem, are really the most hopeful of all. Those whose knowledge is crude because they are receptive to a fault and over-credulous have their critical faculty undeveloped.

Fulness of knowledge, as an active quality of the mind, must be regarded in two aspects, receptivity in the acquisition and readiness in the reproduction. The one is the necessary complement of the other. Receptivity is dependent upon that law of affinity in the nature of the individual learner which might be called idiosyncrasy. In the early and more impressionable years it is plastic, and then a habit of receiving may be formed. Bacon has some pithy observations here. "Certainly custom is most perfect when it beginneth in young years: this we call education; which is in effect but an early custom. So we see in languages, that tone is more pliant to all expressions and sounds, the joints are more supple to all feats of activity and motions, in youth than afterwards; for it is true the late learners cannot so well take up the ply, except it be in some minds that have not suffered themselves to fix, but have kept themselves open and prepared to receive continual amendment, which is exceeding rare." The art of the teacher here is betimes to discover the bent of the learner, and to make the first prospect of the "undiscovered country" of know-

ledge easy and attractive. He must be all things to all that he may gain some. The pupil may from temperament be apathetic, from caprice antagonistic, while the teacher may be unsympathetic, formal, tactless; and in such unhappy conjunction the land of knowledge will prove but a Sahara for both.

There is more scope for the art of the teacher in developing the faculty of reproduction or reminiscence. Its use appeals at once to the sense of power and of pleasure in the highest degree, and therefore it has in itself a constant incentive. Plato has said that all knowledge is remembrance. Even on the practical side one's knowledge cannot be of much service unless one can reproduce it. The great agent in this is the representative faculty or all-shaping imagination. As we are constituted it is a universal gift, though too many of us hide it in a napkin. A well-worn aphorism declares that there is nothing in the intellect which was not previously in the sense. This truth is implied in the word "idea," which, apparently most abstract, in reality means a mental picture, the image of the external form in the mind. This picture, being wedded to its symbol in speech, becomes recognisable and recoverable. So considered, the study of words is the fascinating resuscitation of dead metaphors. Hobbes called words the counters of wise men, but the money of fools. The best tool in the teacher's workshop is this power of visualising, and fortunate for him and still more for his pupil if he be dowered, though in humble measure, with the poet's gift of vivid, graphic, sympathetic speech. The power of recovering knowledge is popularly called memory, and the want of this is supposed to cover a multitude of the learner's sins. As man has a sneaking propensity to bless what he is inclined to, while at the same time the weakness of vanity is ever lying in wait for him, he is apt to regard forgetfulness as evidence of greatness of mind. "See how I have got on without that common drudge, Memory," he in effect says, "I don't need to keep my eye ever on the drill-master's Attention!" While curiosity or interest is helpful in securing a receptive attention and thereby a strong impression, the habit of association will go far to facilitate the recovery of impressions. As it is impossible to keep before the Mind's eye any but an infinitesimal proportion of these, memory, through association, becomes an art of forgetting, or holding in reserve our stock, as money in the bank "at call." There is a law of continuity in all our bodily or mental

energisings. To proceed from the known to the unknown is a safe rule. Surprise bewilders, unless in humour, where it acts as a stimulant. But one who propounds a riddle or conundrum is held to have spoilt the pleasure if too ready a solution has been found. In teaching any nexus of association will serve almost, no matter how whimsical, accidental, or arbitrary. Many impressions come back momentarily into the mind unbidden and even undesirable, and many again are so trifling that we wonder how they ever came into being at all. We reach a higher plane when the knowledge we have acquired is not only held in reserve, but ostensibly dispensed with as the scaffolding is, when the building it served has been finished. This is the argument for the utility of those studies which formed so much of the recruit-drill of school, studies which, though apparently dropped, still shape the thinking of real life, still give back-bone to the scouting and skirmishing with the enemy in the field. A powerful aid to association through the visualising power of the imagination is the habit of discovering logical affinities in the facts of consciousness. This is the only justifiable form of guess-work, that form of it which, in the hands of the scientist, becomes hypothesis. It may always be practised in humbler spheres. There are few cases in which a thinker may not say to himself, when reminded of a forgotten fact of consciousness, "Now, I ought to have known that." The judicious teacher will lose no opportunity of showing how his pupil ought, by the use of his own reason, to utilise his previous knowledge in the solution of fresh difficulties. This was the method of the greatest of teachers, Jesus and Socrates. Even the blundering pupil may be skilfully guided in this quest over ground already trodden, albeit with imperfect observation. In any case "telling" is but a lame remedy for ignorance. This "giving a lead" on the part of the teacher requires much time and infinite patience, but the habit of ready inference yields pleasure as well as power. Even a blunder, if it brings out individuality, however feeble, has in it some elements of vital force.

Bacon, regarding his subject from the point of view of the student educating himself in the best method of acquiring and using knowledge, naturally put writing last as merely a mechanical aid, but exactness is a vital accomplishment and an indispensable tool even in the early stages of the quest for truth. By nature he himself was not at all an exact man. It was incompatible with

his pronounced artistic temperament. Exactness is a homely and far from showy accomplishment, whereas Bacon ever expatiated in the sphere of large thoughts. Quick, as he says himself, to see the resemblances of things, he lacked the plodding virtue of patient introspection. Half truths, as having in them the potency of suggestion, were more pleasing to the artist in language, as he was. He trained himself, however, to see that exactness was not his strong point, so he emphasises its place in his scheme. "No course of invention," which is with him the putting together of known facts from which to draw new principles, "can be satisfactory unless it be carried on in writing." It is significant of the place held in his day by "policy," that in the Essay on Negotiating he thinks it is generally better to deal by speech than by letter. One is sometimes led in a letter, from a love of phrasing (which is just posing), into over-strained expression, but one may as readily say, in the heat of discussion, what may be ever afterwards regretted. In both cases the situation is much one of temperament or training. Again, while fluency of speech seldom accompanies accurate reasoning, the oral discussion more readily assumes the art of the advocate, free to drive home the points which at the moment are felt to tell, while using the secondary ones as skirmishers.

Exactness cannot be acquired without the use of language, and that includes not words only but arithmetical symbols and mathematical formulæ. In the latter case the exactness is conspicuous, but its rigid standard should always be applied to words as well. Of Bacon's third species of Idols, or preconceived shadowy notions in contrast to the "divine ideas," Abbott says, "Language is a third imposture" (Idol) "almost inherent in human nature, pretending to supply nothing but the expression of thoughts, but, under the mask of this pretence, tyrannising over and moulding thoughts." Locke makes a strong point of the ambiguity or want of mutual intelligibility in the use of general terms by two disputants. This places the realising of the full significance of words in the front rank of studies. There is no antagonism between the study of words and of things, provided the same rules are applied to both. Language is every whit as natural and as necessary to us as our limbs or our senses. It provides us at once with materials for study and with tools. Nor does the study fall behind the observation of Nature in interest and pleasure. It is at once the miraculous among our gifts

and the handmaid of all. As the true sense of a word is that which is understood by its intelligent users, it is of the utmost importance to develop at an early stage the faculty of appreciating that usage of a word which most exactly fits the work it is wanted to perform, a process precisely analogous to the skill of the workman in selecting and handling the tool designed for the job. It is this inevitable fitness which characterises the diction of the masters of style. The intelligent grasp of the "content" of a term, the visualising in the concrete of buried metaphor in words, the formation of derivatives, these can all be studied at every stage of reading practice. And, as in the natural sciences biology gives new interest and meaning to function, so in the study of words regard should ever be had to their life history and affinities. When we are subjecting language to this exact study, the quality of the matter read must be kept in view rather than the quantity. The literature of a language is too vast for the study of any one man. The student must apply the time-honoured methods of classical study to Chaucer, Shakspeare, and Milton, and the rest of the immortals. Everything they wrote is full of suggestion. It is not so much a matter here of fulness of knowledge as of appreciation. Their books must be regarded as human documents and a revelation of a human personality.

The practice of exactness, acquired through the study of classical diction and structure, is analogous to the working of problems in mathematics. It may be regarded, on the side of technique, as the practice of original composition, or rather of imitation of the models studied. The most obvious method for acquiring exactness is that of note-taking, always identified with the student. It has its evils to be guarded against, and of these the worst is its tending to encourage laziness. So much easier is it to note a fact than to think it out in all its bearings and assign it its place in the mind. It fosters, too, the whole brood of laziness,—credulity, half-knowledge, blundering, and imperfect generalisation. The best means of cheating the lazy habit is sustained interest, careful explanation, deliberate pace, judicious selection; for it is possible not to see the wood for the trees. The use of such tricks of association as anecdote, diagram, picture, joke and the like helps. Above all the teacher must see, by examination and correction of the notes if possible, and by frequent and persistent revisal, that what he has said has been understood. He must regard the

study of language as laboratory work, and keep his eye and hand on it accordingly. In this way it will promote habits of attention, neatness, concise arrangement; and at the same time it will provide a ready test of acquired intelligence as well as preserve evidence of the ground gone over. It will correct waste arising from inattentives, dullards, and absentees; for in the dissemination of knowledge as of seeds the prodigality of Nature is enormous. By allowing of judicious selection of the essential it economises time.

Analogous to the note-book for class or lecture-room is the diary or common-place book. Bacon recommends this for the young man who goes on his travels:—"Let him keep also a diary." He notes with how little discrimination this is practised at sea, where nothing is to be seen all around, but rarely on land, where so much is to be observed, as if chance were fitter to be registered than observation. Something similar happens in the scholar's life. Few youths would dream of thus committing to paper even an apprentice record of their mental growth, yet that record would be invaluable, and, in the making, a source of lasting pleasure. Whately puts the case very fairly. "It conduces much to mental improvement to keep a common-place book, in which to record any valuable remarks heard in conversation or thoughts occurring to your own mind. And you should not scruple to put down the crudest and wildest speculations, since, when you are writing for no eye but your own, you will not have committed yourself to any erroneous views. Besides other advantages, it will help to cultivate an easy, unaffected style; since, when a man is writing only for his own use, he will write not as if he wanted to say something, but as if he had something to say." From the point of view of the future literary artist a record of good sayings, character sketches, impressive scenes, momentous incidents, will provide a store of workable material. It is good to strengthen the memory by trusting to it, but this is a treacherous ally; for unless our mental furniture is in regular use or repeatedly turned over, it rapidly slips out of reach or deteriorates. If the young scholar is encouraged to note down facts that impress him by their truth or novelty, quotations that are worth prizing for their wit and appositeness, even dates and significant words, with the circumstances of their emergence, he will be *making himself* in the fashion of the artist or the field naturalist. There is unique

gratification in being able to supply exclusive information just when it is wanted. The practice of making abstracts also contributes greatly to the student habit of exactness. The attempt to combine clearness and strength with the use of the fewest possible words is worth more than the covering of reams of essay paper, an exercise of doubtful profit, for it is vain to look for anything like originality in the usual elaborate, long-drawn-out production that passes for the school or college essay. In all but a very few cases it is a waste of time for writer and reader. Poverty of thought, laziness, or both, infallibly leads to servile imitation. An excellent compromise is to have a set of selected books, useful and pleasant to read, to be passed round a class in handy sections; and, a reasonable interval being allowed, an account of each book to be written out. Such co-operative reading is at once economical and encourages emulation. The ordinary school library rarely serves any good purpose. The effort to show something tangible for private reading and to submit it, for comparison, to the judgment of another, is a humble but quite practicable form of authorship. On the same lines the habit of independent research in books of reference gives a surprising interest to useful study. If the object of the search be a quotation, date, term, or fact that can be reasonably got at; and, if the quest arises incidentally to the study in which it originated, it should not be told by the teacher but be left for home research. An endless field for research, easily accessible, is the Bible, Shakespeare, Scott's novels and narrative poems, and the like. If the teacher is himself a student, genuinely interested in intellectual culture, his influence will tell in the best possible direction. Nothing will do more than all this to neutralise the deadening effect of modern mechanical class-book methods, class-books, too, which are never half studied. As a technical aid to composition the paraphrase has little to recommend it. There are other and far better ways of arriving at the desired result. Translation, for example, has a legitimate place in school. It is possible to make from another language a good piece of English, but is the ordinary pupil likely to improve by a paraphrase upon the classical model supplied by his own tongue? There is no need whatever for paraphrasing if another language besides the mother tongue is studied, and, without this, culture through literature is at best imperfect.

When Bacon made Conference the agent in producing readi-

ness, he was evidently regarding the gift of reasoned and persuasive utterance as the crown and flower of the intellectual equipment, not only of the man of affairs, but of every one who aspires to play his part with success or distinction among his fellows. The essays on Negotiating, Discourse, Simulation and Dissimulation, all emphasise this aspect of the subject. It is the note running throughout the essay on Discourse. "Discretion of speech is more than eloquence; and to speak agreeably" (in a manner suited) "to him with whom we deal, is more than to speak in good words or in good order." Amid the crooked policy of the age, and the cross currents of Reformation times it was a great point in the game of life to know when to be open, and when to be reserved. A subtle observation is this of Bacon's, "Men rather discharge their minds, than impart them." Confession for the ease of unburdening the heart assumes the guise of an apparent communication of inward thought. His rule of conduct in speech is deeply significant of the man and his times—"The best composition and temperature is to have openness in fame and opinion; secrecy in habit; dissimulation in seasonable use; and a power to feign, if there be no remedy." His Antitheta[1] present a subtle series of maxims on the comparative merits of candour and reserve. "Silence is a virtue in none but confessors . . . The silent man has no secrets told him . . . All kinds of constraint are painful, but of silence most of all . . . Thoughts are like water, most wholesome when they flow." On the balance Bacon, as was to be expected of one who was full of apostolic fervour in the pursuit of knowledge, commends the virtue of openness; but, as was natural in one whose soul, like Milton's and Carlyle's, dwelt apart, he inclines to reserve:—"Nakedness is uncomely as well in mind as in body; and it doeth no small reverence to men's manners and actions if they be not altogether open. As for the talkers they are commonly vain and credulous withal, for he that talketh what he knoweth will also talk what he knoweth not." In ordinary social intercourse, however, between equals, the balance is entirely in favour of openness, real or disguised; for the communication of knowledge is highly congenial to human vanity. It needs either temperament or strong will to restrain this form of social joy. Ordinarily when

[1] Bacon's "Antitheta" are designedly half-truths, presenting the pros and cons of the argument under discussion.

a man is reserved in opinion, it is from lack of sympathy, due to opposition, ignorance, indifference, or, most potent of all, deficiency in imagination. As an illustration of the art that conceals art in handling reserve, Whately's "modern instance" will serve :—"A certain banker bequeathed to his son a flourishing business, together with a large and very strong iron chest, securely locked, which had always been supposed full of gold. "To tell you the truth," said he, "the chest is empty; but if you keep the secret, the secret will keep you." Many support a reputation for wisdom on the empty chest.

Conversation is barren and formal without that mutual sympathy which has a tender regard for fair play in avoiding masterfulness, tediousness, and mere personalities. Jest and satire are equally to be condemned. As Bacon says, "There be some that think their wits have been asleep except they dart out somewhat that is piquant and to the quick—that is a vein which would be bridled. And, generally, men ought to find the difference between saltness and bitterness. Certainly he that hath a satirical vein, as he maketh others afraid of his wit, so he had need be afraid of others' memory." As kindly, self-effacing talk not only gathers knowledge but evidences a bond of sympathetic interest, the vanity of a display of wit is fatal to that sincerity which is the savour that keeps conversation sweet. It was the indiscreet Ben Jonson, not "sweet Will," that would sooner lose a friend than spoil a jest. Akin to such suggestions of insincerity is that tendency, more or less inherent in all of us, to put into what seems to be an expression of opinion, or a statement of fact, or observation of sense, elements due to temperament, caprice, feeling. This is but that artistic lie which we are all prone to, when setting off our conversation. "A mixture of a lie," says Bacon, "doth ever add pleasure. Doth any man doubt that, if there were taken out of men's minds vain opinions, faltering hopes, false valuations, imaginings as one would, and the like, but it would leave the minds of a number poor, shrunken things, full of melancholy and indisposition" (for action) "and unpleasing to themselves. But it is not the lie that passeth through the mind, but the lie that sinketh in, and settleth in it, that doth the hurt." We have here a subtle statement of the part played by temperament in the intercourse between man and man that is dependent upon speech. Bacon's own unbounded faculty of self-deception was an "imagining as he would"—such as ever gives large thoughts and impressive utterance.

The value of Conference, with all its helps and hindrances, is powerfully illustrated in the communication of knowledge in the classroom. There was a time when to teach was to hear prescribed tasks and dictate formal precepts and the dry bones of catechisms, all to be repeated with or without understanding. The material, probably most excellent in itself, was doled out without much regard for the capacity of the receiving mind, or the natural fitness, for the occasion, of what it had to receive. Authority was everything, individuality nothing. Not till last century was well under way was the expository or explanatory method much practised, and this originated, not in the privileged grammar schools, but among a few outsiders and enthusiastic theorists. In the higher walks it was contemporaneous with the appearance of the mother tongue as an agent in intellectual discipline. The classical master never conceived that English could of itself be of any account in mental discipline, or that there was anything in it that called for explanation. The explanatory method owed much to the introduction of the infant school training as an advance on the ignorant dame, her hornbook and dunce's cap. The extension of the method brought into prominence the essential value to the teacher of the Baconian trinity, fulness, accuracy, and readiness; while it established the preeminence of the mother-tongue in the educational process. An old maxim of the schools has said that no one can be held to know a thing till he can make another know that he knows it. This points to conference or the interchange of ideas, the exposing of them to the corporate light, as the final test of all instruction, and in this the teacher must play the leading part. He ought to come to his task with a well-informed mind and a trained understanding. Whately puts the position well—"True wisdom consists in ready and accurate perception of analogies. Without the former, knowledge of the past is uninstructive; without the latter, it is deceptive. . . . One complaining of not being understood is one who does not well understand himself."

Scott, speaking of his teacher, the estimable Adam of the Edinburgh High School, says that only some share of vanity could have made the inherent drudgery of his position possible. The teacher has indeed what might be called the vanity of the artist, the consciousness of clearer vision, of wider prospect, of higher purpose. He has in him some ground for that intellectual pride

of which Milton made so much, for to him knowledge is power. But though Adam did something to humanise his work, the old method served only to raise a wall of partition between the learner and the learned. Vanity in the popular sense, however, may be dismissed as incompatible with a trained and well-balanced intellect. A vicious type of it is that austerity of the formalist and the martinet which excludes sympathy with every one but itself. It is due to an inherent imperfection in respect of manner or of method or of both. Formality in method is useful in the early stages of instruction, but, in the later, initiative is to be fostered at all hazards, just as, in military education, the practice of the drill ground is only a preparation for independent scouting in the field. This sympathy dictates what is the determining motive in most speaking, persuasion, leading to the acceptance of knowledge or opinion and a consequent course of action. It is the transference *ad rem* of one's personality to another, and this is alone possible where the speaker can work upon that corporate sense which we call sympathy in common interests and a common pursuit. In this way the teacher not only commends his instruction but imprints on the plastic mind of youth his own personality in ways alike of thinking and of acting. His fluency and fulness should bespeak a love of knowledge, his accuracy should reveal the critical habit of the scholar, his readiness and sympathetic interest should persuade to imitation. An impression of perfect candour, without affectation or pretence, is a strong persuasive. One of Bacon's Antitheta is, "Though we cannot think according to the truth of things, yet let us at least speak according as we think." To speak with simplicity convinces of earnestness. The young are quick to recognise the hollow ring in grandiloquence, artificiality, and speaking for effect. They dislike the prig among themselves who speaks like a book. Equally distasteful ought to be the pedantic and the pulpit style. The unfailing security for naturalness on the part of the speaker is absorption in the subject, which comes, of course, from sympathy. Two powerful auxiliaries will be a keen interest in garnering and methodising knowledge and a gift of apt illustration, for one must be prepared with many baits to "catch your carp of truth."

Conference, as implying the use of language in speech, opens up what ought to be regarded as the crown of the whole edifice of culture, that is, the subject considered in its social aspect. Apart from the mutual pleasure of such intercourse, one's know-

ledge is probably not of much value if one cannot reproduce it. As the aim here is, not only to convey information but, to give pleasure, the emotions come prominently into play. Reading now becomes not the solace of the student as recluse, searching the world of books for knowledge, but the charm of the entertainer. The art ceases to be a mechanical device, and becomes expressive and dramatic. Vocal expressiveness is the life and soul of persuasion, and that is the object of most speaking. It comes, above all our gifts, by nature, for physically it is based on voice and ear. For the former, right methods of using throat and chest may do something, while the confidence which comes from ease acquired by practice will help. Ear is largely the power of vocal imitation, always prominent in early youth but rapidly weakened with the growth of self-consciousness as individuality begins to assert itself. Just as the social tone which we call manners, is mainly the product of environment, so intonation or accent takes its character from familiar surroundings. This accounts for dialect, which is imitation in spite of oneself. It is comparable with those early habits which are conducive to conduct, whether good or bad. We are strangely inconsistent here. In the learning of foreign languages we approach the matter from the adult point of view, exaggerating the importance of a pure accent, whereas command of language is the first requisite and not the insistence on the need for having a Parisian or a Hanoverian tutor. On the other hand, where the mother tongue is concerned, with its ready and growing supply of words along with an excess of bad examples in the shape of gabble, slipshod, and the defective utterance of the lazy speaker, we accept without question a nurse or servant steeped in dialect. The formal and limited restraint of the lesson, again, produces a stiffness in contrast to the natural easy flow of out-of-doors utterance. It is often observed that those who approach expressive reading from a ready use of colloquial English, as, for example, the urban children of the imperfectly educated, have more pronounced faults of utterance than those, say, in the Highlands or in Ireland in a less degree, by whom English speech is acquired more readily from books and teachers. The Highlander's speech may be faulty in its phonetics, but is beautifully clear and precise. The part played by the understanding in expressive reading is much feebler than that on the imitative side of voice, ear, and environment. The reading of clergymen, un-

doubtedly a highly educated class, and alive to the value of expression in oratory, is, in the average, much wanting in the qualities that give pleasure to the listener. The unfortunate elimination of Bible reading in favour of the sermon, in the old Scotch service, killed out this form of expression. Distinctness and correct pausing, as due to reflection, may be present in the reading of the intelligent, but these are not the most effective factors in expression. There may be intelligibility without emotion. The critical faculty sees the point, but there is no white heat. In the statement of the logical points of a legal plea this is in place. Emphasis and speed ought both to be ruled by the intelligence, but are too frequently under the influence of temperament. The understanding, for example, prescribes a pause of some kind before a conjunction and a preposition, never after, yet the type of pause in "The boy stood on / the burning deck" is one of the commonest. No one would pause so if speaking his own thoughts. To most, reading is a mechanical matter and no more, whereas speaking is naturally dramatic and under impulses that are essentially dramatic.

As striking success in expressive reading is possible only to those who have special talent, a great deal more ought to be made than is made of original utterance and its training. The American citizen owes much of his power of fluent, clear, pleasant speaking to the republican atmosphere he breathes, yet the educational methods under which he is reared contribute largely to the result. The mediæval devotion to the text-book, and the dictated doses of didactic wisdom live in philological minuteness and the tyranny of the written examination. The most frequent field for practice in the power of recalling knowledge at command is oral questioning. We fail to regard it as a valuable exercise in composition and accept fragments of speech as answers. Bacon, though he has in view discourse in real life, has much to say that is suggestive to the questioner and questioned in school. "The honourablest part of talk is to give occasion and again moderate" (be moderator or director), "and pass to something else, for then a man leads the dance. He that questioneth much learns much and contents much, but specially if he apply his questions to the skill of the persons whom he asketh. For he will give them occasion to please themselves in speaking, and he himself shall continually gather knowledge. But let his questions not be

troublesome for that is fit for a poser; and let him be sure to leave others their turn to speak." The last clause suggests a much neglected method of stimulating dramatic interest. The conventional practice is for the teacher to do all the questioning and the pupil the replies. The position should be more largely reversed.

For successful oral answering there is needed fulness of knowledge and readiness in drawing upon the stores acquired. A great obstacle is diffidence, due to inability to think aloud quite as much as to nervousness. On the theory of continuity of thinking surprise is to be avoided, for the mind more readily links on to a previous thread than takes up an entirely fresh one. The latter power, that of instant mental detachment and attachment, is the rare faculty of presence of mind. By judicious excitation of association, the use of reason, and hints as to the proper mode of guessing, which is really the drawing of inference, even the slow-witted will move, and that is half the battle. Bacon truly says:—"Discretion of speech is more than eloquence: to speak agreeably" (as suits the understanding) "to him with whom we deal is more than to speak in good words or in good order." A professor, who had been a Senior Wrangler, and was accepted as an educational expert of repute, was examining a class of boys, all under fourteen, in my hearing, on the "Deserted Village." The passage:—

> "She, wretched matron, forced in age, for bread,
> To strip the brook with mantling cresses spread,"

suggested this appalling order, "Discuss the force of the epithet 'mantling' here." This scientist forgot that the oldest of the sciences is Common Sense. Blundering is the counterpart of diffidence. Bacon thinks that nothing so much excites suspicion as the knowing too little, evidently alluding to a lack of candour on the side of authority, but the blunderer is candour itself. His faculty of introspection is atrophied. A mathematical professor, examining a particularly obtuse specimen of his class, exclaimed in despair:—"I hope, Mr ——, you will some day discover the depths of your ignorance." But the mental eye sees itself with exceeding difficulty. Working with a limited stock of mental capital, the blunderer lives on a hand-to-mouth indebtedness to any suggestion, any false scent of a pre-conceived notion, any straw which shows the

wind he should lazily float on. A fertile source of the blundering which leads to misunderstanding between questioner and questioned is imperfect definition of terms used. Those who proclaim the superiority of things to words in education, in so doing, wofully neglect the indispensable tool and inspirer of right thinking. Definition is indispensable to mutual intelligibility, a truth Locke long ago insisted on. The imperfect grasp of technical terms is indeed a dangerous thing, but once thoroughly understood they are precise bundles of knowledge. To the student they have all the definiteness of proper names. The very first step we make on our introduction to a strange person or place is the correct name of each, and then the path is at once smoothed to wider knowledge. Here is a justification of note-taking, and precise definition, and frequent repetition, with oral and written examination to secure accuracy. Sometimes the very arbitrariness of the technical term serves to fix it in the memory and thereby attach it to a mass of floating correlated knowledge. This is the place of the anagram as a mnemonic. Examples that are never forgotten are Vibgyor, from the initials of the prismatic colours, the *Ichthus* or fish-symbol of the Catacombs, from the initials, in Greek, of "Jesus Christ, God's Son, Saviour;" Voltaire, from his real designation, Arouet le jeune. Dates are quasi-technical terms, which, by a judicious use of association with striking circumstance, clever grouping, undesigned coincidence, and every species of collateral interest, may be made a powerful agent in the rapid, pleasing, and permanent acquisition of knowledge. The date 1616, besides being in itself a remarkable group of figures, marks Shakespeare's death. That he lived as many years as there are weeks in a year settles his birth. Curious coincidences are Dryden's birth and death (1631-1700) and Cowper's (1731-1800), or, again, Plassy (1757) and the Indian Mutiny (1857).

An admirable combination of oral questioning and oral composition, leading to that readiness in speaking which calls upon all the acquired resources of pupil and teacher, is the encouraging of the pupils to address the class, each in turn, on some subject which has been carefully prepared. The Germans know it as the Vortrag, the Americans as Recitation. It was a recognised practice in Grammar School and College in the 17th century. Such is our national reticence and exaggerated individuality that we use it least where it would be most effective, in the universities.

In comparison the wearisome written examination, the laboured, pointless essay, which absolutely blunts the sense, physical and mental, of the examiner, these are all a grievous misdirection of effort. These Vorträge would be invaluable for the future teacher, lawyer, or clergyman. Instead, they are all duly subjected to the conventional round of essay and written examination. The "lecture" combines fulness in research, exactness in ordered arrangement, and readiness in communicating results. It breaks up the isolated position in which the teacher stands to the pupil, too often deadening in its effects, and that of the pupils to each other. It generates a true spirit of independent thinking, and neutralises cram. It appeals to the corporate feeling in inviting friendly candour and the criticism of fellow-workers, if it be combined with oral questioning both of, and by, the lecturer. In Scotland, for centuries, we have worked—professor, preacher and teacher—on a mediæval platform of isolated authority, speaking without coming into living touch with the minds spoken to. Of course the "lecture" may turn out only a memorised essay, a dead inanity like the read speech or read sermon, which is such a powerful agent in the physical and mental somnolence of the pew. If this cannot be avoided in the case of those who are unable to shake off the inroads of unwise habit, a corrective will be found in the free use of questioning, which must largely be spontaneous. Thus the "lecture," in being mainly undesigned, becomes at once the best, because natural, practice in thinking aloud, and the best test of good speaking. The effort of thus thinking engrosses the attention and secures naturalness, so difficult to attain in what is called elocution, an exercise which serves its purpose as a vocal drill, but when the class-room is turned into a forum we have true dramatic utterance in which all the social instincts of communion with our fellows play their part.

Dr Abbott finds, after a searching analysis of Bacon's practical philosophy, that religion is carefully excluded from the "Essays," the treatise that is to pass into the business and bosoms of men. "He writes like a philosopher, or like a courtier, or like a statesman, but rarely or never like an orthodox Anglican." This Anglican attitude is natural to an Episcopal D.D., but need not be insisted on as a universal guide to human conduct. In Bacon's day practical religion was mainly a matter of politics, church or national. Right belief regulated conduct only as far as that

conformed to a right form of church polity. Dr Abbott says of Bacon :—"In his nature passionless, the Christian religion was seldom recognised by him as having a powerful influence on human conduct except in the perverted form of superstition." Many opinions thrown out in the "Essays" support the satire in Crowe's lines :—

> "Our better thoughts
> Are as our Sunday garments, then put on
> When we have nought to do ; in working days
> We wear our worst for thrift."

But when the discourse is of Science, Bacon has all the vision divine and fervour apostolic. The Apocalyptic imaginings of Spenser and the Spenserians, which beheld as the goal of the devout life on earth the ultimate Union of the Bride or the pure Church and Christ, her Lord, become in Bacon's fancy the Union of the Mind of Man with the Mind of the Universe. In keeping with the spirit of his age he entertained low views of human nature. The student of social history sees in the record of many centuries, with its tale of cruelty and violence, of superstition and intolerance, a wide-spread contempt for any spark of goodness that might be in the unfortunate victim of his own or others' faults. As Abbott says :—"Bacon believed something was to be learned from poets and historians, that might be useful for the Art of Advancement. But that by studying the brother whom we have seen we may expect to learn something of Him whom we have not seen, this is not taught in Bacon's theology."

Bacon in his essay on "Nature in Men," says it is, "often hidden, sometimes overcome, seldom extinguished." This nature is that disposition or "inclination to goodness," which we call temperament, or the mixture in us of our inborn qualities. Custom or environment is the agent in modifying natural disposition. Aristotle expresses the same thought when he says that, if children are early accustomed to right practice, they will form virtuous habits. The word for custom in Greek gives us ethics, and in Latin, morals. To this effect is Bacon's saying :—"Men's deeds are after as they have been accustomed. Let parents choose betimes the vocations and courses they mean their children should take ; for they are then most flexible, and let them not apply themselves to the dispositions of their children, as thinking they will take best to that which they have most a mind to. If the affection or aptness of the children be extraordinary, then it is

good not to cross it. Generally the precept is good :—Choose the best, and custom will make it agreeable and easy." It is debatable what influence intelligence has on conduct. The Reformers made much of doctrine or the inculcation, in early years, of virtuous maxims, but this did not seem to relieve the strain on church discipline. There were then some remarkable examples of early piety. At seven, James Melville "lernit to abhore swearing, and rebuk and complain upon sic as I heard swear." Dr Abbott has small faith in "the superficial goodness of childhood and youth, those raw and unripe virtues which can only be called virtues by hopeful anticipation." With reference to Bacon's Collegiate Custom as a great reforming influence, he regrets that Bacon has not worked out the practical application. It is the keystone of the English Public School system. In schools, if anywhere, such custom is "in exaltation;" yet of Schools the Essays contain no mention. Indeed, Bacon seems to have attached little importance to the sowing of the educational seed broadcast through England. Of popular education neither Bacon nor any other thinker had, for centuries, any conception. He expressly states that he thinks there were too many Grammar schools, basing his opinion on the fact that education incapacitated for the lower walks of labour, while, in the other direction, more young men were highly educated than the State could employ, with the consequent fostering of the elements that led to revolution.

In the practical field of educational work, Bacon could not go beyond the ideas of his age. The beautiful life and teaching of More remained Utopian. The shade of Orbilius and his ferule still dominated what was assumed to be the only royal road to learning. But Bacon wore his "rue with a difference." "For roughness it is a needless cause of discontent. Severity breedeth fear"—evidently considered not to be out of place—"but roughness hate. Even reproofs from authority ought to be grave and not taunting . . . Certainly anger is a kind of baseness, as it appears well in the weakness of those subjects in whom it seems —children, women, old folks, sick folks." It is certain that anger, whether in the shape of the satirical gibe for the dullard or the grave rebuke for the froward, never carried any one far on the road to learning. One aspect of corporal punishment in school is often overlooked. The offender is made to feel that, having given the satisfaction exacted, he is now on even terms with authority, and

can henceforth devote his thoughts to the contemplation of his own self-esteem. In after years he can expatiate on his sufferings as the most memorable triumphs of his school career. Better the teacher should hold, with Bacon, that the power to do good is the true and lawful end of aspiring to a position of authority. Bacon finds a place even for judicious flattery. "A cunning flatterer will follow the arch flatterer, a man's self; and wherein a man thinketh best of himself, therein the flatterer will uphold him most. Moderate praise used with opportunity, and not vulgar, is that which doeth good . . . In fame of learning, the flight will be slow without some feathers of ostentation." Nothing so favours such growth as the consciousness of success in any measure, and the approbation it brings. The love of commendation leads to greater effort. Bacon thought "too much magnifying of man or matter doth irritate contradiction and procure envy and scorn," but an appeal to the corporate sense or public opinion will blight such unworthy thoughts. All such praise is unwisely bestowed if it is reserved for the brilliant. "To him that hath shall be given," too often holds in the intellectual world. The favoured elements by Nature will look after their own efficiency. The diffident and the slow find in the approbation which has discovered virtue in them an incentive that is indeed doubly blest. But the unsatisfying rôle generally left to them is that wittily suggested by Bacon—"The little dogs find the hare but the big ones catch it."

Bacon was a Humanist, a child of the New Learning, and as such the practical aim of education was, in his eyes, the development of a high standard of intellectuality. He had been "suckled in a creed out-worn," the scholastic philosophy of Aristotle, which during the Middle Ages had pursued reasoning as an end in itself. With the wider outlook that followed printing, gunpowder, the discovery of the New World, there never had seemed to him greater need for awakening the intelligence of England. Like that modern Pagan, Queen Elizabeth, the Reformation affected him nought, for both subordinated religion to policy. The schools did nothing for him, for they most emphatically were un-reformed. Hence to him education was self-culture, and after all to this conclusion must come every sober-minded teacher. This characteristic of his theory, the enthroning of intelligence, was further exemplified in the teaching of Milton and Locke; and together these master-minds gave a trend to subsequent culture in England. The

contrast with Scotland is marked. As Professor Hume Brown has shown, Scholasticism lived on, and ruled there, while purity of doctrine was a *sine qua non* as a security against the counter-reformation which was always threatening in the shape of Prelacy or Popery. Thus the wider outlook in education was subordinated to the needs of the church, and these prescribed the scholastic array of well-ordered argument. There was no Bacon in Scotland. Knox, if he were the only begetter of education there, learned all he knew about it from John Sturm of Strassburg, and Calvin in Geneva. These men worked on scholastic lines. Nothing shows in a stronger light the dominant influence of the needs of the faith as interpreted by the Church in Scotland than the fact that, whereas in 16th and 17th century England, quite half a dozen books were written on education, that still live in literature, not one can be claimed for "beyont the Tweed." Of these books not one is more profoundly suggestive, or of more vital importance than the "Essays" of Bacon. Even this, however, was but the vestibule of the vast temple he designed, *The Instauration of the Sciences*, his unfinished scheme of Technical Education.

CENTENARY LECTURES, No. VI.

Developments in Electric Signalling during the Nineteenth Century.
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[Prepared by request of the Council and delivered before the Society, 11th January, 1905.]

WHEN the Council of this Society asked me to prepare a paper on the Developments of Telegraphy and Telephony during the Nineteenth Century I fully expected to get considerable help from a perusal of the previous volumes of the *Proceedings* of the Society. The only paper I could find on Telegraphy was one "On Telegraphic Communication between Great Britain and Ireland," by Mr W. J. Macquorn Rankine and Mr John Thomson, read on 17th November, 1852. The authors maintained that the best route for a submarine Electric Telegraph between Great Britain and Ireland was by the Mull of Cantyre, as the breadth of the channel there was less than 13 miles, while the breadth between Portpatrick and Donaghadee was 22 miles. Among the other arguments used they stated that the scheme proposed would be fraught with great local benefit to the West of Scotland and the North East of Ireland.

Between 1881 and 1893 there are six papers bearing on Telephony, one by Professor Blyth, three by Mr D. Sinclair, and two by Mr William Aitken.

I have received most help, however, from my own colleagues, Mr T. Hetherington, and Mr William Allan, lecturers on the above subjects in the Department of Electrical Engineering in the Technical College. To them I wish at the beginning to offer my cordial thanks for the efficient and enthusiastic aid they have accorded me.

The first proposal for an electric telegraph was made by Mr Charles Marshall of Paisley, in the *Scots Magazine* 1753. There he gave a full description of a practical telegraph in which frictional electricity is employed for the transmission of signals

through a wire coated with insulating material. This was the origin of the application of electricity as a means of communication.

In the subsequent years of the century many ingenious attempts were made to construct a telegraph, but the task of maintaining a constant source of electrical energy and of insulating the currents presented obstacles insurmountable by the knowledge and resources of the time.

These attempts rarely proceeded beyond the laboratory stage. Yet one of them in the beginning of the nineteenth century, developed by Sir Francis Ronalds, was carried further, and is interesting on account of the energy and confidence with which it was pursued by its originator, who erected a wire 8 miles long in his garden at Hammersmith.

In this case both open line and underground were represented. The open wire was placed on wooden supports and insulated at the attachments by means of silk. The underground wires were enclosed in glass tubes which were surrounded by a wooden trough filled in with pitch.

For the signalling apparatus two clocks were fitted with dials on the seconds arbours. These dials were engraved with the letters of the alphabet, but a screen in front of them allowed but one letter to be seen at a time. In front of the clock two pith balls were kept divergent by a frictional machine at the sending station. When the required letter was in view the sending operator discharged the line, causing the pith balls to collapse. This indicated to the receiving operator the letter signalled. [Slides shown.]

Ronalds sought to bring his invention to the notice of the Government. In reply to his invitation to Lord Melville to witness the experiments he received the following :—"Mr Barrow presents his compliments to Mr Ronalds and acquaints him with reference to his note of 3rd inst. that telegraphs of any kind are now wholly unnecessary, and that no other than the one now in use will be adopted." This was issued from the Colonial Office on the 5th August, 1816.

Ronalds was in advance of his age. With wonderful foresight he saw the value of an electrical means of communication. His "Description of an Electric Telegraph" published in 1823 (the first book on the subject), might also serve as a description of the present-day telegraph system. He proposed the establishment of

telegraph offices throughout the kingdom, described methods of connecting them by overhead and underground wires, with details of jointing, testing stations, staff of linemen and inspectors; and pointed out the benefit the Government would derive from such a system. All the same those in authority left it to private enterprise to develop the telegraph.

By and by advances in science turned the attention of inventors from frictional to voltaic electricity. The voltaic pile was described by Volta in a letter to Sir Joseph Banks, written from Como in 1800. Immediately afterwards Nicholson and Carlisle discovered the chemical effects of a current of electricity. On these discoveries S. T. Sommering, surgeon in Munich, based a system of telegraphy. Thirty-five wires were used, terminating in gold points, placed in thirty-five glass tubes, which dipped in a vessel of water. At the transmitting station a metal terminal was fitted on each wire. The two poles of a voltaic pile were brought into contact with two of the terminals, causing a current to flow round the circuit, disengaging hydrogen and oxygen in the corresponding tubes at the receiving station. Two signals were thus given simultaneously, of which hydrogen took precedence, representing the first letter of the pair signalled. But Sommering's system was obviously cumbrous and costly.

Oersted's discovery in 1820 of the deflection of a magnet by an electric current gave a new impetus to inventors. It suggested to Laplace among others the idea of employing the deflections of a magnetic needle for telegraphic purposes. This idea was taken up by Ampere, who in a communication to the Academy of Sciences, Paris, dated October, 1820, said :—

"If a keyboard, whose keys were each marked with a letter of the alphabet were adapted to the battery so that on pressing down the key of any letter the circuit corresponding to that letter would be closed, correspondence could be carried on with ease and would require only the time necessary to press down the keys at one station and to read off the letters from the deflected needles at the other."

This simply involved the substitution of needles for the voltameter tubes of Sommering. Ritchie, Professor of Natural Philosophy in the Royal Institution, furnished each needle with a small screen covering a letter of the alphabet, which was exposed when the needle was deflected. This instrument was exhibited in Edinburgh in 1820. But like Sommering's these systems were

unsatisfactory because of the number of wires required. The use of a code of signals with a corresponding reduction in the number of wires does not seem to have as yet suggested itself; though in development in this direction really lay the solution of the problem of constructing a commercial telegraph. Meanwhile Fechner of Leipzig suggested the use of one needle, the deflections of which to left or right would form a code of signals; but the palpable utility of the suggestion was unrecognised, and for ten years no advance was made. Doubts appear to have arisen also regarding the possibility of transmitting currents of electricity through a conductor of great length. No constant battery was yet available. The law of Ohm had not been made known to the world, and consequently experiments in conduction were wrongly interpreted. In 1827 Dr Green, of Jefferson College, Philadelphia, wrote:—"In this early stage of electromagnetic experiments it had been suggested that an instantaneous telegraph might be constructed by means of conjunctive wires and magnetic needles. . . . There was only one question which could render the result doubtful. This was whether by lengthening the conjunctive wires there would be any diminution in the electrical effect upon the needle. . . . Mr Barlow (Professor Barlow of the Royal Military Academy, Woolwich), fully ascertained that there was so sensible a diminution with only 200 feet of wire as to convince him at once of the impracticability of the scheme." Latimer Clark's comment on this in his Presidential Address to the Society of Telegraph Engineers and Electricians in 1875, is:—"There can be little doubt that this published opinion of so eminent a man as Professor Barlow which occurs in the Philosophical Transactions had the effect of retarding the introduction of the Electric Telegraph by many years."

Interest in the telegraph revived in 1832, this time to be maintained to the memorable year 1837. Models of an electric telegraph (still preserved in St. Petersburg Academy of Sciences), were exhibited in 1832 by Baron Schilling of Cronstadt, who based his system on the suggestion of Fechner to use a code of signals. Five needles were employed. Gauss and Weber, then occupied in their historical researches in electrical measurements, developed a single needle telegraph on similar lines; and it was from having seen one of Schilling's instruments at Heidelberg that W. F. Cooke was led to devote himself to the task of devising some regular system of telegraphy.

The work of Gauss and Weber was in reality but subsidiary to their scientific labours at Gottingen. The account of it occurs in a report on their magnetic observations (Pogg. Ann. 32, p. 568):—

"There is in connection with these arrangements a great, and until now, in its way, novel project, for which we are indebted to Professor Weber. This gentleman erected during the past year a double wire line over the houses of the town (Gottingen) from the Physical Cabinet to the Observatory, and lately a continuation from the latter building to the Magnetic Observatory. Thus an immense galvanic chain is formed in which the galvanic current, the two multipliers at the ends being included, has to travel a distance of nearly two miles. The ease and certainty with which the manipulator has the direction of the current, and therefore the movement of a magnetic needle in his command, suggested experiments of an application to telegraphic signalling, which with whole words, and even short sentences, completely succeeded. There is no doubt that it will be possible to arrange an uninterrupted telegraphic communication in the same way between two places at a considerable distance apart from each other."

Professor Steinheil of Munich, in response to the request of Gauss took up the development of this telegraph. He showed its commercial practicability by working over a line several miles in length between the Royal Academy, Munich, and Bogenhausen. But his chief contribution to the telegraph, was made accidentally while experimenting on the Nuremburg railway to ascertain if the rails could not be used as conductors. He found that the earth would act as a return circuit. Step by step advance was made from 35 wires to 5, from 5 to 2, and by the use of an earth return to the present-day practice of 1 wire.

W. F. Cooke's work in this country began on his return from Germany in 1836. A year later, through the influence of Faraday, he was brought into contact with Professor (afterwards Sir Charles) Wheatstone, and a partnership was entered into between them. Cooke's energy, sanguine temperament, and practical mind, combined with the marvellous ingenuity, fertile intellect, and wide knowledge of Wheatstone, forced telegraphy into public notice. Railways had come into extensive use, and concurrently with the development of rapid transit, arose the need of a rapid method of controlling the traffic. In 1837 Cooke and Wheatstone produced their five-needle instrument. On 25th

July, trials were commenced with it between Euston and Camden on the L. and N. W. Railway, this being the first commercial telegraph erected in the kingdom. In 1840 a distance of thirty-nine miles on the Great Western line was furnished with this telegraph, but owing to its cost—£250 to £300 per mile—its use was not extended. [Slide shown of Wheatstone's five-needle telegraph, patented in 1837.]

But the five-needle instrument did not long survive. Economy demanded fewer wires. Cooke and Wheatestone reduced the number of needles to two and adopted a code of signals. [Double needle instrument exhibited]

Finally they introduced the single needle which is in use to the present day, both in the Post Office Telegraphs and on the Railways of the United Kingdom. It is a non-recording instrument, but its simplicity, the absence of complicated adjustments, and the ease with which a number of offices may be placed on one wire, have enabled it to hold its own against later methods. [Types of single needle instruments were exhibited, and their action explained.]

While Cooke and Wheatstone were developing the needle telegraph in Britain, S. B. Morse, was working on other lines in America. The discovery of Oersted was the foundation of British telegraphs. American telegraphs began with the Morse system which was based on the use of the electro-magnet.

Arago and Davy had in 1820 observed independently that a wire in which a current was flowing attracted iron filings, and they also showed that a strip of iron placed in a helix of insulated wire became magnetic. Later in 1825 Sturgeon constructed large electro-magnets; and just before Morse took up his work on the telegraph, Professor Joseph Henry in America had greatly increased their lifting power. These discoveries were attracting general attention.

Morse, while returning from France to the United States in 1832, made the acquaintance of a Dr Jackson, who had with him an electro-magnet and two cells which he described to Morse. In course of conversation they discussed Franklin's work, and touched on the application of electricity to telegraphy. The novelty and promise of an electric telegraph immediately fired Morse's enthusiasm. For four years he worked at the problem, and in 1836 brought out what is now known as the Morse telegraph system. Subsequently the conversation on board ship

led to an acrimonious and prolonged litigation between Jackson and himself respecting priority of invention, the outcome of which was entirely in Morse's favour.

On the 27th September, 1837, the latter wrote to the Secretary of the Treasury of the United States promising to have a complete set of his apparatus in operation on the 1st of January, 1838. An experimental line, half a mile long, was erected in October, 1837, but the first commercial line of telegraph was not opened until 1844, when Washington and Baltimore were connected.

Nine years were spent in endeavouring to create enthusiasm and confidence in financial circles in this country. At first the telegraph was confined to the railways. Stephenson recognised its value and adopted it on the Blackwall railway in 1840. Next year Sir Charles Fox ordered one for the Glasgow and Cowlairs line. New railways in other parts of the country were furnished with it, but to the inventors of the telegraph the financial results were almost disastrous. Cooke appears to have provided the capital for the various undertakings, and after five years his deficits amounted to over £6,000. This uphill fight continued till 1845, when public attention was incidentally drawn to the value of the telegraph through the flight of a murderer named John Tawell, Slough, being prevented by means of its use. Financial support was thereafter promptly given ; the Electric Telegraph Co. was formed ; and the succeeding three years saw the erection of 1,500 miles of wire. The large towns were linked, and in five years the business attained to a sound footing. It was considered a very remarkable feat when London, Birmingham, and Manchester, were placed in direct communication in 1849.

For the next two decades the telegraph remained in the hands of private companies. The pioneer company, the Electric Telegraph Co., used the needle system and Bain's recorder, the latter a modification of the Morse system, in which signals in that code were printed by chemical action on a strip of paper, instead of being embossed. The paper was treated with a solution of potassium ferrocyanide. It passed over a metal roller and on it rested a platinum style. The signals were printed in clear blue by the decomposition of the electrolyte caused by the line currents passing between the style and the roller. [Slide of Bain's chemical marking system shown.]

The Magnetic Telegraph Co. used Bright's Bell, a modification of the needle system. In this case the signals were rendered

audible by means of two bells, one of which indicated dots and the other dashes. This obviated the necessity of watching the movements of a needle and tended towards quicker working. [Slide shown, and instrument exhibited.]

Two other instruments, Wheatstone's A B C and the Hughes Type Printing Instrument were used by the Universal Private Co. and the United Kingdom Telegraph Co. respectively.

The A B C system of Wheatstone had been brought out in 1848. The communicator which forms the transmitting portion of the apparatus is a small alternate current generator. A compound horseshoe magnet has two soft iron pole pieces fitted with coils placed on each pole. These coils are placed symmetrically with respect to an axle carrying a soft iron armature. This axle is geared with the driving wheel, which is revolved by hand. Above the electrical mechanism is a dial marked with the letters of the alphabet, and a pointer. The motion of the armature and pointer are so related that for each current generated, the pointer moves forward a letter. The currents are controlled by a system of keys arranged round the dial. When a key is depressed the currents instead of passing to the line, are cut off, and simultaneously the motion of the pointer is arrested. The act of signalling consists in turning the driving wheel, and at the same time manipulating the keys so as to spell out the word signalled letter by letter.

In the indicator or receiving apparatus the alternating currents pass through two electro-magnets between which is pivoted a polarised armature. The end of the armature distant from the electro-magnets is fitted with an escape wheel engaging with two pallets and springs. Each oscillation of the armature forces a tooth of the escape wheel against one of the pallet springs, which propels the wheel forward. The wheel carries a pointer which revolves in front of a dial corresponding with the one in the communicator. The receiving operator follows the movements of the pointer as it spells out its message letter by letter. Wheatstone's A B C apparatus is the simplest of all forms of telegraph to work, and is still used throughout the kingdom in village telegraph offices where the employment of skilled operators would not be justified by the small quantity of work dealt with. [Slides shown.]

In 1859 the Hughes' Type Printing Telegraph was introduced and was first used by the newly formed United Kingdom Telegraph Co. [Slide shown.]

This instrument is extremely simple in its electrical arrangements, but complicated mechanically. The sending apparatus resembles a piano keyboard with the alphabet and other signals engraved on the keys. Type wheels at the sending and receiving stations are made to rotate synchronously; short intermittent currents governed by the keys release the wheels simultaneously and cause them to strike a strip of paper on which the message is recorded. The instrument is largely used on the Continent at the present day, and the cables from this country to the Continent are fitted with it.

The needle, the Morse, the A B C, and the Hughes instruments were the principal ones in use at the time of the transfer of the telegraphs to the State in 1870. From this time onwards developments in speed and multiple transmission have been in the hands of the Post Office.

The tariffs of the private companies were prohibitive excepting in cases where urgency made absolute necessity. The freedom with which the telegraph is used in the present day could not be indulged in when a telegram might cost as much as 12s. 6d. One of the early tariffs was, for 20 words, one penny per mile up to 50 miles; then ½d. per mile up to 100 miles; and ¼d. per mile above 100 miles, addresses included. A telegram of 20 words from Glasgow to London would thus cost over 12s.

The restriction which this graduated scale according to distance imposed was felt to be irksome. Although the submarine cables are universally worked under tariffs which are founded on the "mile-word" basis—corresponding with the "ton-mile" of the railways and similar undertakings—the British public as early as 1860 began to ask for a universal rate for the United Kingdom. The outcome was the formation of the United Kingdom Telegraph Company to introduce a universal shilling rate. But the competition of the other companies proved too keen for the new departure, and it was abandoned.

In 1865 the following tariff was adopted by all—for twenty words and free addresses.

Within London and other towns, - - -	6d.
„ 100 miles, - - - - - - -	1s.
„ 200 „ - - - - - - -	1s. 6d.
Over 200 „ - - - - - - -	2s.

As had been anticipated the reduction in tariff brought an increasing volume of work. The total number of messages paid

for in the United Kingdom in 1852 was 211,000. It was 6,830,000 in 1869. The increase was not uniformly spread over the Kingdom. The Companies confined their operations to the large towns where the business was profitable. There were no village telegraph offices. Two thousand nine hundred offices existing in 1869 probably served less than two thousand towns. Consequently as the telegraph had gradually assumed the character of a necessity, especially from a commercial point of view, its extension to all centres of industry, even though they might be but comparatively small, was urged. To secure this extension the State was called upon to purchase the inland system, and in 1870 the transfer to public control took place. A universal 1s. rate for twenty words, addresses free, resulted in an immediate increase of 30 per cent in the work, (6,830,000 telegrams in 1869; 9,850,000 in 1870), and the village post-office became a telegraph office too.

With this growth in traffic came the demand for increase in the number of channels. The wires were over-loaded. Manual transmission with skilled operators, under favourable conditions, could not greatly exceed forty words per minute, and this speed was perhaps impracticable with the average operator. Thirty to forty telegrams per hour was satisfactory working. In addition, sudden rushes of work due to numerous causes—Royal visits, public speeches, race meetings—called for additional outlets; and when storms rendered whole routes useless the value of any method of relief became apparent. The extra demand was met in three ways. First more wires were built. Second, the automatic system or machine transmission was introduced, in which the signalling is performed automatically at speeds greatly in excess of those possible by manual transmission. And third, the methods of multiple transmission, known as the duplex, quadruplex, multiplex, were adopted. By these systems two or more messages are signalled simultaneously in opposite directions on one wire.

The automatic fast speed instrument, principally developed in Britain and America, was Wheatstone's apparatus, based on the principle of preparing messages for transmission by perforating the signals on a strip of prepared paper, which latter could afterwards be passed through an automatic transmitter. The latter, acting as an extremely rapid Morse key, translated the perforations into dots and dashes—short and long pulsations of current delivering the message at the distant station in perfectly formed

signals, similar to and better than those made by hand. Bain devised a system of automatic telegraphy in connection with his chemical recording telegraph in 1848. Augustus Stroh took up the matter in 1866, and with great skill improved the mechanical details of the transmitter. Post office investigators carried on the improvements, and to-day the instrument is capable of transmitting six hundred words a minute.

[A Wheatstone automatic transmitter was shown working and sending messages at the rate of four hundred words per minute over a short line.]

In 1875 the maximum speed of simplex working on our land lines did not exceed 100 words per minute. This limit was imposed not by the mechanical capabilities of the transmitter, but by the electrical properties of the wires and apparatus. A wire suspended on poles is subject to two defects telegraphically considered. Each support forms a path of leakage for the current. On long circuits this is of considerable importance, for when the insulation resistance of the circuit falls below its conductor resistance, the limit is passed which determines the practicability of working at the highest speed possible on that particular circuit. The exacting requirements of high speed working demand good insulation. Further, the wire possesses electrical capacity; it resembles one coating of a Leyden jar, of which the other coating is the earth and the objects, trees, houses, etc., surrounding the wire. When a current is transmitted along it a portion is absorbed in raising the potential of the wire. The signal is retarded. On the other hand, on the cessation of the signal proper there follows a prolongation due to the discharge of the accumulated electricity. Where considerable lengths of underground work are included in a circuit, the retardation and distortion of the signals become pronounced. And finally, in addition to the contest against bad insulation and electrical capacity, the early telegraphists had difficulties presented by the impurity of the materials used for the conductors. The employment of copper for submarine cables had led to exhaustive investigation into the conditions to be observed during manufacture to secure a high conductivity, and when the makers succeeded in increasing the tensile strength, hard drawn copper wire was introduced on our land lines. This had the effect of increasing the speed of working, due not only to the reduced resistance, but also to the diminution of electromagnetic inertia in the circuit.

In the apparatus the chief hindrance to rapid working lay in the inductance of the electromagnets of the receiver, which slowed down the rate at which the current rose, and caused a lagging in the action of the instrument. In 1881 shunted condensers were employed to counteract the effects of inductance.

The Wheatstone automatic apparatus, working direct, provides for high speed working over circuits of not more than 200 miles. Beyond this length the difficulty of maintaining speed has led to the introduction of repeaters. The strength of the current received compared with that sent on a circuit decreases with the length of the circuit. If this were due simply to increased resistance it could be met by additional battery power. But the effects of weather on the supports result in a lowering of the insulation resistance, and an increase of the leakage at the supports. In Britain the conditions are such that it is difficult to maintain direct communication for distances over 400 miles. It therefore becomes necessary on long circuits either to retransmit the telegrams at an intermediate station, or introduce a repeater or translator, which, worked by the original currents will automatically repeat them with renewed power. A London-Amsterdam circuit without repeater will work at a speed of 116 words a minute, and with a repeater at Lowestoft the speed becomes 400 words per minute. The line of the Indo-European Cable Company from London to Teheran, which is 3,800 miles long, is worked with only two re-transmissions by means of eight repeaters.

The gain in speed brought about by the insertion of a repeater near the centre of a circuit is fourfold. The law governing the speed of a telegraph wire, may be simply expressed $W = C/KRL^2$

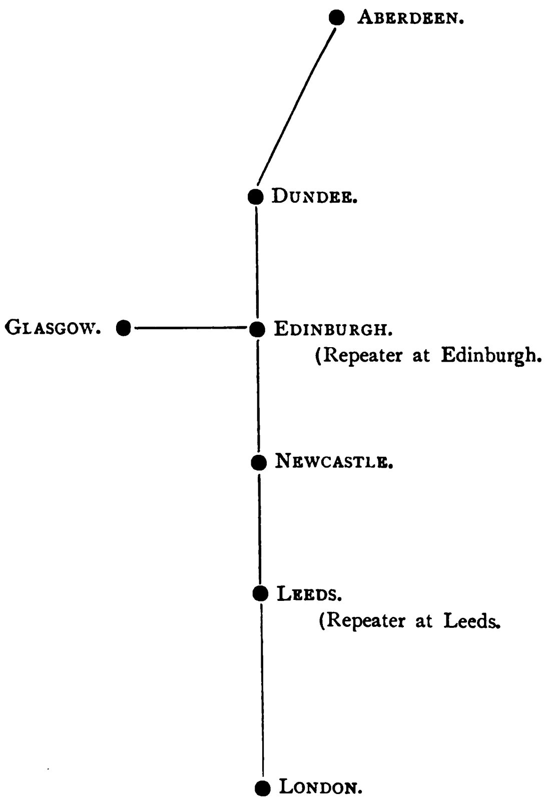
where W = maximum number of words signalled on line under consideration.
„ C = constant depending on the nature of the line, etc.
„ K = capacity per unit length of the line.
„ R = conductor resistance „ „
„ L = length of the line.

This shows that the speed varies inversely as the square of the length of the circuit. Hence halving the line, and by means of a repeater, working each side independently results in a fourfold increase in the speed of the whole circuit.

The use of high conductivity copper wire for the conductor, and improved methods in the construction of the aerial lines, com-

bined with a corresponding improvement in the mechanical construction of the apparatus, and a better knowledge of the electrical principles involved, have made it possible to transmit telegrams at a rate of 450 words per minute between London and Dublin, and 250 words per minute between London and the North of Scotland. It is with such circuits that the large volume of news for the daily newspapers in all parts of the country is dealt with. London is the centre from which the News Agencies distributed the daily reports of political, commercial, and foreign intelligence. As the reports are frequently identical for several towns, the latter are placed together on one circuit, and each receives the reports simultaneously at high speeds.

Typical News Circuit. One wire with extension to Glasgow. All stations receive news at 250 words per minute.



Concurrently with the development of the automatic system, progress was made in perfecting the duplex, quadruplex, and multiplex systems. Duplex working enables two messages to be transmitted simultaneously in opposite directions on one wire. While A is working to B, B can also work to A. Two operators are provided for each end of the circuit; one attends to the signalling, the other to the reception of the telegrams. Each works independently of the other, and consequently the carrying capacity of the circuit is doubled.

The problem of duplex working was first solved by Dr Gintl, an Austrian telegraph director, in 1853. His method known as that of *Equation*, consisted in using double-wound receiving

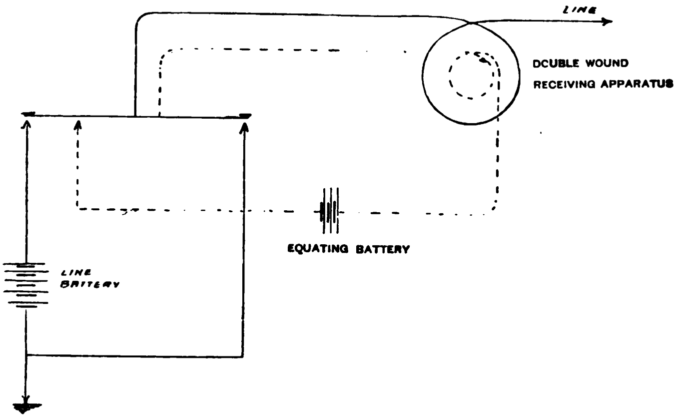


Fig. 1. GINTL EQUATION METHOD.

apparatus, and an "equating battery" circuit, arranged as shown in Fig. 1. The equating battery consisted of a few cells only, and the equating circuit of a comparatively thick wire of a small number of turns on the electromagnet of the receiver. The magnetic effect of each current was, however, balanced against the other. Signals had thus no effect on the home station apparatus, but line currents received from the distant station were unopposed, and free to produce signals.

Experimentally Gintl's method worked beautifully. It was tried in actual work between Prague and Vienna, but did not then prove so successful. Several causes militated against it. The line and the equating batteries were doing different work. They

varied badly; and added to this the variations in the conductor resistance of the line circuit due to changes of temperature and other causes, could not be reproduced in the equating circuit, for adjustable resistance boxes were unknown. Moreover, the detrimental effects of the static discharges arising from the capacity of the wire were not understood and were ignored.

A modification of Gintl's original plan—the differential method—devised simultaneously and independently by Siemens and Frischen in 1854, was more successful. Still, the demand for the duplex was not great enough to urge inventors to contest the electrical difficulties, and it was not until 1870 that duplex working became firmly established, when the volume of traffic had grown to such an extent that multiple transmission began to be a desideratum. About this time J. B. Stearns, in America, took up the

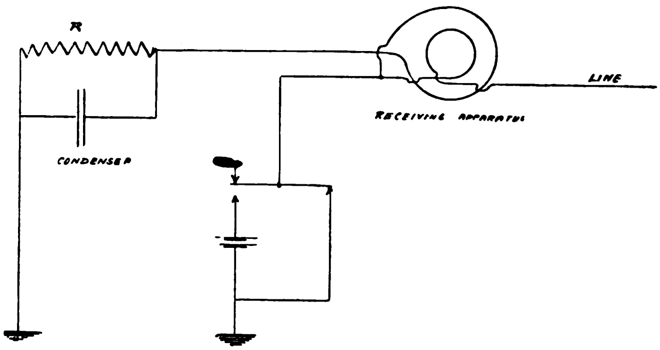


Fig. 2. DIFFERENTIAL DUPLEX.

problem. He introduced the Wheatstone bridge method, and showed, too, the value of introducing a condenser in the artificial circuit to imitate and nullify the effects of capacity in the line circuit. On land lines in this country the differential duplex is universally adopted; the bridge method is more general in America, and is used on all cable circuits.

The principle of the Differential Duplex is that if two paths of equal resistance be open to a current, the latter will divide equally between them. Let the electromagnet of the receiving apparatus be wound with two wires of the same length and of the same resistance. Arrange the connections so that one of these wires is in the line circuit, and the other in the artificial, or compensation circuit, as shown in Fig. 2. In the compensation circuit place a

resistance R equal to the line resistance plus the resistance of the apparatus of the distant station. A condenser is placed across the resistance R. The compensation circuit is then a reproduction of the line circuit, and the action is similiar to that already described in Gintl's method of duplex.

In the Wheatstone bridge system of duplex (Fig. 3) the line forms one of the arms of the bridge. The resistances R_1 R_2 R_3 being adjusted to give balance, the points *a*, *b*, will be at the same potential, and consequently no current from the battery at the home station will traverse the receiving apparatus. Currents from

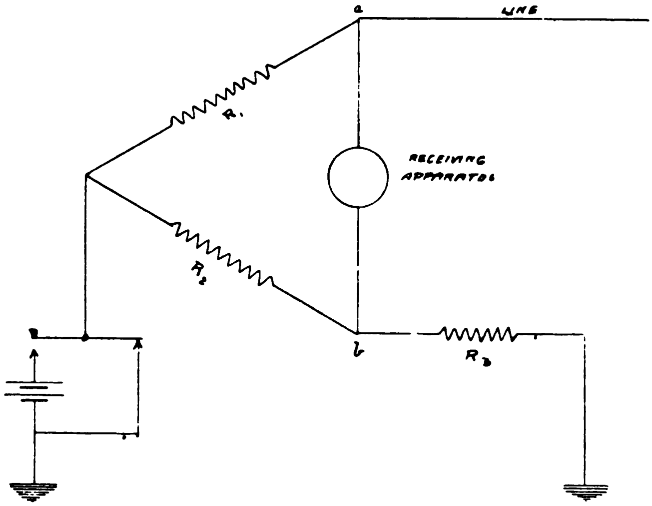


Fig. 3. THE BRIDGE METHOD OF DUPLEX.

the distant station will divide at *a*, in proportion dependent on the resistances, and signals will be received on the receiving apparatus. Differentially wound apparatus is not required, and this is an advantage of the bridge method.

The step from the duplex to the quadruplex was made by Edison and Preston in 1874. On long circuits double current working was displacing the earlier single current method in which the receiver was simply an electromagnet with a soft iron armature. Double current working consists of the application of a second current reverse in direction to the signalling current proper, and

following immediately after it, to hasten the clearance of the line of the charge accumulated on it, or in other words, to annul the bad effects of the capacity of the circuit. Polarised instruments are required for the receiving apparatus. In these the armature of the electromagnet is permanently magnetised, and the apparatus becomes responsive to changes in the direction of the current. Edison conceived the idea of combining double-current and single-current apparatus on one wire. He worked out the plan, and produced the quadruplex. The method is as shown in Fig. 4.

A current flows constantly; change in strength operates one relay; change in direction operates the other. The first relay is of the non-polarised form, fitted with an antagonistic spring on its armature and so adjusted that it fails to respond unless the normal

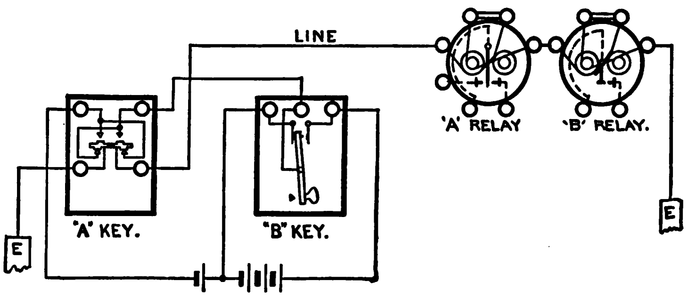


Fig. 4. Principle of Quadruplex System.

current is considerably strengthened; and the second relay, having no springs, responds to a reversal of the current, whether this be of normal or of augmented strength. The sending apparatus consists of two keys, of which the single-current key increases the strength of the current without affecting the direction; the double-current key changes the direction without interfering with the strength. Four operators are employed at each station, two for signalling, and two for receiving messages.

Duplex apparatus is fitted on every circuit of importance, and in all large offices the quadruplex is found. Fast speed Wheatstone working is combined with both quadruplex and duplex—the former combination frequently multiplying the carrying capacity of the circuit twelvefold. It is also practicable to introduce quadruplex working between three towns in such a way that the principal terminal station works on the double current side

to one town, and on the single current side to the other town. Thus—

GLASGOW.
4 Operators :—
2 on double current side.
2 on single ,, ,,

(One Wire only.) BRADFORD.
2 Operators on double current side.

SHEFFIELD.
2 Operators on single current side.

Many attempts had been made in the first half of the century to construct a cable suitable for immersion in water. The difficulty lay in the insulation of the wire, the insulating materials first used being tarred hemp and india-rubber strip wound spirally round the conductor. Seams and interstices could not be made water-tight, and thus the insulation of the circuit was never satisfactory. With the introduction of gutta percha to this country in 1843 a plastic material capable of being moulded round the wire became available, and Siemens in 1847 devised a machine for covering wires with this substance without seams or joints.

In 1848 Messrs Siemens and Halske laid several hundreds of miles of gutta percha covered wires for the Prussian Government, and they also laid similar wires in Kiel harbour in connection with submarine mines. As inland telegraphs became firmly established, and the value of rapid communication appreciated, proposals to link England and France by cable were made.

In 1847 Messrs Brett obtained a concession from the French Government to establish a submarine telegraph between the countries. Vicissitudes of various kinds, financial and practical, delayed the work for three years. Not till 1850 was a cable

consisting of a No. 14 copper conductor covered with half an inch of gutta percha first laid across the Channel. Communication through it by means of a Cooke and Wheatstone needle instrument followed for a few hours, but only on the day on which the laying was completed. The work, however, was not altogether abortive. It dispelled the idea that the electric current would become dissipated in the water in spite of the insulated covering, and showed that what was wanted was a cable of a mechanical strength sufficient to withstand injury during laying, and the chafing on the bottom of the ocean caused by tides, etc., after it was laid.

In September 1851 a second cable was successfully laid across the Channel. In this one four conductors insulated by gutta percha formed the core which was enclosed in a sheathing of ten stout galvanised iron wires. The mechanical strength thus given to the cable protected it from the strains and chafing which had so quickly destroyed the cable laid in the previous year. Telegraphic communication was thereby for the first time permanently established between England and France. Following this success cables were laid between Scotland and Ireland, England and Holland, and England and Germany, and in less than ten years half-a-dozen excellent cables connected this country with the Continent.

The year 1857 witnessed a more ambitious attempt. This was to lay a cable across the Atlantic Ocean. The greatest length of line previously submerged was that which stretched between Varna and Constantinople, a distance of 171 miles, at an average depth of 100 fathoms. Data applicable to the length necessary to span the Atlantic were non-existent. Both from the mechanical and electrical standpoints the work was really of the nature of a huge experiment.

Under the auspices of the Magnetic Telegraph Co. financial support was secured, and in August of the above year the work began. When only 274 nauts of the cable had been laid a break occurred in 2,000 fathoms of water, and operations were suspended. It had become evident that the paying out gear needed improvement, and at the same time fears were entertained that sufficient cable had not been provided to allow for slack. The vessels engaged in the work returned to Plymouth, where they were fitted with improved gear, and took on board an additional 700 nauts of cable. On the resumption of work the

following year, tremendous difficulties were experienced, but with dogged perseverance the expedition brought their efforts to a successful conclusion, and signals were exchanged between Ireland and America on the 5th August, 1858. For twenty days the communication was maintained. Then a fault developed and the cable became useless. The cause of the disaster was never definitely ascertained, but the currents obtained from induction coils at probably 2,000 volts were generally considered to have contributed to it. Notwithstanding the final failure of the undertaking it had demonstrated the possibility of laying over 2,000 miles of cable in ocean depths of 2 to 3 miles, and of successfully transmitting electric signals through this great length of cable.

During the next seven years the network of cables in the seas round Europe, Asia, and Africa, increased steadily, till over a hundred were in operation in 1866.

Having overcome the physical difficulties associated with the laying of cables, it forthwith became a matter of prime importance to determine the conditions governing the speed of working them. The capital outlay necessary to provide a cable between Ireland and America, for example, added to the cost of maintenance when laid, demanded that the speed should be as high as possible. Increase in speed meant a corresponding increase in revenue. The first step in the solution of the problem was to discover the general law governing the propagation of an electric current in the conductor. This was done by Professor William Thomson (Lord Kelvin) in 1855—just before the original Atlantic cable was laid. He gave the mathematical theory of the phenomena, and by means of his "curve of arrival" showed graphically the general law. [Slide of "curve of arrival" shown]. His investigation was so thoroughly complete that this curve may be used for all cables and all distances if the value of the unit length along the axis of time (abscissae) be properly chosen. The unit length, commonly called the retardation, has a value for a given cable

$$KR \times 10^{-6} \times 0{\cdot}02915$$

where R = conductor resistance in ohms of cable.

K = capacity in microfarads of cable.

This is the time which will elapse before the current begins to appear at the distant end. The form of the curve shows the manner of the current's growth.

Attention was at once directed to the determination of the

most advantageous dimensions of conductor and insulating envelope—for the product of the total conductor resistance into the total capacity of the cable governs the retardation, and con sequently the speed of working. Another important fact illustrated by the curve, referred to the degree of sensitiveness of the apparatus used for observing the signals. If the sensitiveness of the apparatus be increased it will be possible to terminate the current earlier at a point nearer the origin of the curve, than would otherwise be the case.

Following on his theoretical work Thomson introduced (1858) the mirror galvanometer, an instrument of a high degree of sensitiveness. It is difficult to conjecture any modification of the comparatively coarse Morse apparatus as then known, or of any of the then existing apparatus which, in the absence of the mirror galvanometer, would have been found equal to the exacting demands of the first Atlantic cable. Morse apparatus of the most modern form cannot be used on cables of the latest type for distances over 700 miles. With the mirror galvanometer it became possible to terminate the signalling currents in the manner described above and then "curb" them. A signal is curbed in its strength by the application of an opposite current following immediately after it. [Slides of "curbed" currents shown.]

With hand signalling the necessity for curbing is not usually felt. The signals are not fast enough for it to be desirable. Where high speeds are aimed at, speeds for example of forty to fifty words per minute on the later Atlantic cables by machine transmission, curbing is employed.

The next improvement of importance was the use of condensers. By inserting a condenser at each end of a cable, and so keeping the latter completely insulated, the signals are improved. The effect resembles curbing; in fact, many authorities hold that with condenser working it is unnecessary, even with machine transmission, to resort to curbing. The method was first put into practice in 1866, on the Atlantic cable of that year. A speed of 25 words a minute was then attained. See Fig. 5.

For nine years the mirror remained the one instrument in use on long cables. Thereafter, in 1867, Sir William Thomson introduced the siphon recorder. No increase of speed was secured, but the hitherto transient signals could now be recorded. A check on transcription was secured by the record on the slip, which in cable traffic, consisting largely of messages in code and cipher, con-

stituted an advantage. The recorder consists of a light coil of wire, suspended between the poles of a powerful magnet, and having its plane parallel to the vertical plane through the poles of the magnet. It is capable of turning about a vertical axis. When a current traverses the coil, the latter tends to move so as to embrace as great a number of the magnetic lines as possible. The movements of the coil are transmitted by means of silken threads to a small light glass siphon. One end of the siphon dips into a receiver of ink, while the other end almost touches a strip of paper propelled before it at a uniform rate. The ink is either electrified, or vibrations communicated to the siphon cause tiny

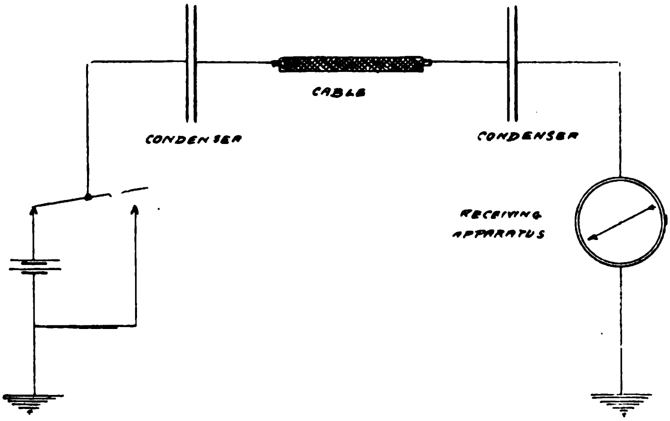


Fig. 5. METHOD OF APPLYING CONDENSERS.

spurts of ink to form a continuous dotted line on the strip of paper, and thus the movements of the coil are recorded. [Slides of instrument and record shown.]

When the duplex method of working had been installed on the land lines (1870-72) the task of duplexing submarine cables was attempted by J. B. Stearns. Short sections of one of the Anglo-American Company's cables were duplexed in 1873, and the main section later on in 1878. Stearns at first adopted the differential method, the siphon recorder being wound differentially. The artificial circuit, representing the cable, was made up of a number of resistances with condensers interpolated as shown in Fig. 6. Stearns, however, found considerable difficulty in maintaining a balance between the cable itself and the artificial line. His method was unfavourably reported on by Mr C. F. Varley and

Professor Ayrton in 1881 and fell into disuse. Concurrently with Stearns in America, attempts were made by M. de Sauty to duplex the Lisbon-Gibraltar cable by means of the Wheatstone bridge method. Success on these lines was later assured, and modern practice is all in favour of the bridge method of cable duplex. An outstanding step in the success, which has enabled almost all cables now in operation to be duplexed, was the introduction by Messrs Muirhead & Taylor of an "inductive resistance" to form the artificial circuit. It is obvious that the type of artificial circuit consisting of resistances with condensers as shunts cannot be the exact counterpart of a submarine cable. An unlimited number of sub-divisions would be necessary to imitate the distributed resistance and capacity of the cable. The "inductive resistance" is free from this objection; combining

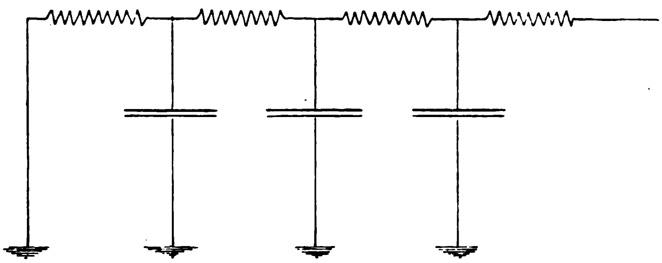


Fig. 6. STEARNS ARTIFICIAL LINE.

throughout, in one, the function of resistance and capacity, as in a cable. Following its introduction in 1875 the duplex system made rapid strides, and few cables now exist on which it is not adopted. It brings an increase in carrying capacity of approximately 90 per cent.

With increased traffic the demand for automatic working arose. An automatic transmitter possesses advantages over manual transmission in that the signals are of greater uniformity, and the speed is limited only by the actual speed value of the cable, which in the latest types is higher than that at which the best operators can signal; and further, the capabilities of the receiving instrument are superior. On the Atlantic cables automatic working is almost exclusively adopted. The speed obtained on the Anglo-American Company's 1899 cable is as high as 50 (five-letter) words per minute, while 47 words per minute are maintained regularly in practice.

Of the various electrical systems which have been experimented upon with a view to transmitting telegraphic signals from place to place without the intervening wires (that is wires stretching from one station to the other) three are worthy of mention :—

(1) The system which makes use of the electrical conductivity of the earth or of water.

(2) That which depends upon electomagnetic induction.

(3) That based upon the fact that an oscillatory spark emits waves which may be detected by a suitable instrument at a distance.

1. As an example of the Conduction method, suppose at the transmitting station a current (continuous or alternating) be sent from a generator through the earth between two metal plates immersed in it at a considerable distance apart. Along any one of the infinite number of stream lines part of the current passes, and if in this line two points be taken, they will be at different potentials. If, therefore, plates be sunk at these points, and joined through a receiving instrument—a delicate galvanometer if the circuit is continuous, and a telephone if it is alternating—the instrument will give indications of the starting and stopping or reversing of the current in the transmitting circuit, and thus it will be possible to transmit messages. This system was used by Morse and Gale in America in 1842, by Wilkins in 1849, by Lindsay in Scotland from 1843 to 1859, by Johnston in India in 1879, by Trowbridge in 1880, also by Willoughby Smith, Tesla, and others.

Lindsay transmitted signals across the Tay, a distance of three quarters of a mile. He had at each station two immersed plates, the two at the sending station being connected through a commutator with a battery, and those at the receiving station being joined by a wire, in the circuit of which was a galvanometer. The results of his experiments so far as he could draw conclusions from them seemed to prove that the fraction of the current from the battery which found its way through the receiving instrument was dependent upon (1) the power of the battery, (2) the area of the immersed plates, (3) the lateral distance, or distance between the two plates on the same side of the river, and (4) it was inversely proportional to the transverse distance, or distance from one pair of plates to the other across the river. Lindsay also experimented at Aberdeen and along, with Preece in London. Willoughby Smith experimented with a view of establishing communication with lighthouses and light ships. For the latter, two wires were run out from the sending station and anchored near

the ship. In the circuit thus formed through the water an intermittent current under the control of a Morse key was sent. From the bow and stern of the ship two plates were suspended, dipping into the water and having in their circuit a telephone by which the Morse signals were received. By this means successful telegraphy was carried out.

2. In 1831 Faraday discovered the principle of electro-magnetic induction; and in 1884 when the telephone was beginning to come into extensive use the importance of this induction was brought to the notice of practical men by the observation of disturbances in telephone wires due to telegraph circuits in their vicinity. In 1885 inductive effects were detected between parallel telegraph lines 10¼ miles apart. This led Preece to conduct a series of experiments to test the possibility of wireless telegraphy on the induction system, and also to find out whether in the case of circuits which were partly wire and partly earth, the effects transmitted were mainly due to induction through the ether or conduction through the earth. An experiment was made in which coils, each of a single turn of insulated wire, 440 yards square, were laid on the ground near Newcastle, and conversation by telephone was conducted through a distance of one quarter of a mile. In 1886 circuits of parallel telegraph lines were chosen on opposite sides of the Severn, and disturbances were transmitted between them at a distance of 4½ miles. The results were found to be practically the same whether the circuits were completely metallic or partly earth. In 1892 telegraphic communication and also speech were maintained across Loch Ness, a distance of 1¼ miles. In the same year, messages were sent across the Bristol Channel, between Lavernock Point and Flathorn, a distance of 3·3 miles. In 1895 communication was maintained between Oban and Mull by induction between parallel wires. In this year an unsuccessful attempt was made to communicate between England and Ireland by two circuits one stretching from Carlisle to Haverford West, and the other from Belfast to Wexford. Nothing but a continual noise was heard in the telephone receiver, although all telephones and telegraphs were stopped for the time. Preece's transmitting arrangement consists of a motor driven circuit breaker which makes and breaks the circuit a convenient number of times, 260 up to 400 times per second, and a Morse key which breaks up the intermittent current further into dots and dashes. The receiver is a telephone. [Slides shown].

Sir Oliver Lodge contributed a paper on "Improvements in Magnetic Space Telegraphy," in December 1898, to the Institution of Electrical Engineers. This contribution and the discussion which followed contain other data and results which I have not space to refer to in this paper.

3. About 1864 Maxwell's electro-magnetic theory of light was published, a theory based on the hypothesis of the propagation of electrical effects by wave motion in the ether. In 1886 the existence of these waves was experimentally proved by Hertz. The latter in the course of his researches found that an oscillatory electric spark was the source of waves, which spreading out in all directions could be detected at a distance, and this discovery is the basis of the many attempts by numerous experimenters to effect telegraphy without wires at considerable distances.

The first spark generator used by Hertz consisted of two brass

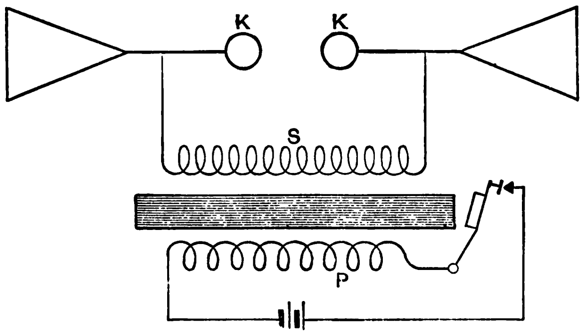


Fig. 7.

cylinders of 3 cm. diameter, and 26 cm. in length with their ends rounded off by spheres of 2 cm. radius. Various types of sparkers or wave generators or transmitters were tried by Righi, Lodge, Sarassin, Marconi, etc., but a common form is simply two balls with an air spark-gap, or four solid spheres with a dielectric liquid between them. Fig. 7 shows the former with wings added to give capacity to the circuit.

Detectors or receivers have taken various forms. The one originally employed by Hertz consisted of "an almost complete loop of wire" across the short gap in which small sparks were observed to pass when oscillating discharges were taking place in the vicinity. But the usual form is one based on the fact that loose metal filings in an electric circuit become more conductive

when electric waves fall upon them. The high resistance of a column of filings seems to have been known as early as 1852 when Varley used such a column as a lightning bridge for telegraph circuits. A few years later, he also discovered that its resistance was greatly reduced by lightning flashes. This was again, in 1886, observed by Onesti who noticed that the impulsive discharge of a previously electrified wire affected the metal filings as to their coherence. The subject was brought into prominence in 1891 by Branly who then announced that mechanical tapping of the tube containing the filings caused them to be fairly non-conductive. The theory of this action most commonly accepted is that propounded by Professor Lodge who maintained

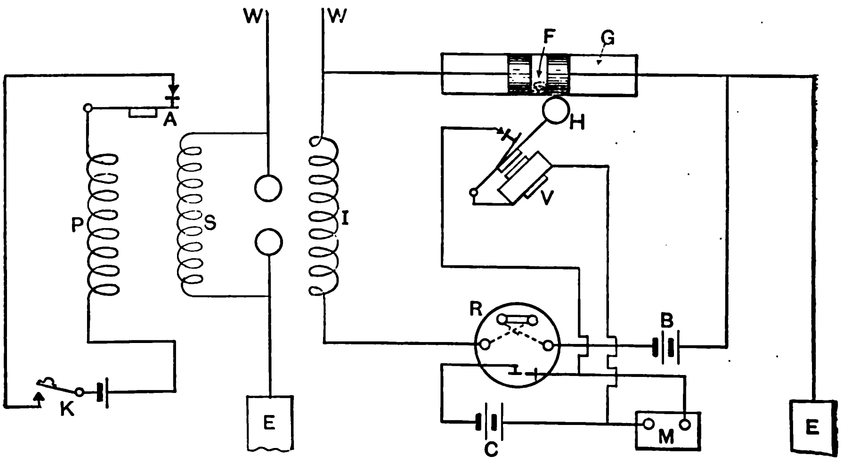


Fig. 8.

that the effect of the electric waves was to cause the filings to cohere at their nearest point of contact. Hence, this form of receiver is called a coherer. The coherer of Marconi consists of a glass tube with two silver plugs one-fifth of an inch long and about one-thirtieth of an inch apart. The space between is filled with a mixture of metallic grains consisting of 96 parts nickel and 4 parts silver with a trace of mercury. The tube is exhausted to a pressure of about one-thousandth part of an atmosphere. In Fig. 8 which represents diagrammatically a simple transmitter and receiver, F G is the coherer and V H the tapper to cause decoherence, R a relay, and M a recording instrument.

Another form of receiver used by Marconi in his trans-Atlantic experiments depends on the fact that the hysteresis of iron is affected by electrical waves. The principle is illustrated in Fig. 9, which shows two coils wound on the same iron core. N S is a magnet kept rotating uniformly in front of the iron core. When electric waves fall on W, a distinct indication of this is given by the telephone T.

A great deal has been written on the methods of tuning not only the receiver but also the transmitter, so that waves of a

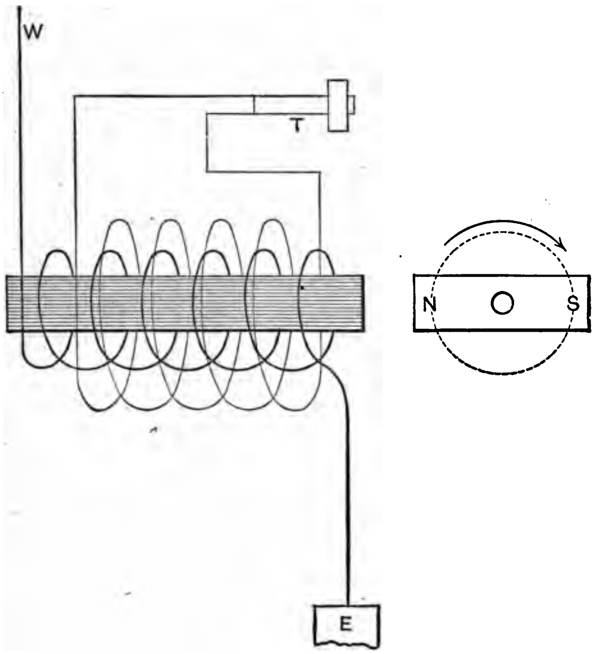


Fig. 9.

predetermined length could be produced and recorded by a particular set of apparatus. As the wave length depends on the inductance and capacity the principle involves the variation of these. Fig. 10 shows diagrammatically the method of doing so. The capacity K and the inductance D of the transmitter can be varied and so can the capacity K^1 and the inductance D^1 of the receiver. In this way it is claimed that syntony can be attained.

The sending of the letter S across the Atlantic from Poldhu in England on 12th January, 1901; the transmission of three

messages from Cape Breton to England on 21st December, 1902; the message from President Roosevelt on 19th January, 1903, to His Majesty King Edward; the Wireless Telegraph Act of 1904; the announcement that on and after 1st January, 1905, the British Post Office will accept messages to be transmitted by the Marconi Company to any of twenty-five Atlantic liners from any of six stations—three in England and three in Ireland—to distances of about 150 miles from the nearest station; all these facts belong to the twentieth century record, and need not be further referred to here.

Other experimenters have done good work with apparatus differing in details from those above described. Among these

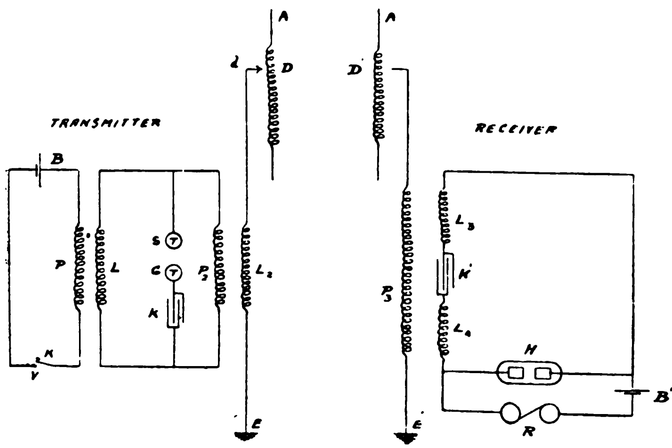


Fig. 10.

may be mentioned Lodge in England, Slaby in Germany, Fessenden and De Forest in America.

Passing now to telephony it may be stated that although Wheatstone produced an instrument as early as 1821, which he called a telephone, the first recorded proposal to transmit sounds by electromagnetic effects was made by M. Chas. Bourseul in France, in 1854. Speaking of his proposal he says:—"Suppose that a man speaks near a movable disc sufficiently pliable to lose none of the vibrations of the voice, and that this disc alternately makes and breaks the current from a battery, you may have at a distance another disc which will simultaneously execute the same variations."

Philip Reis in Germany constructed in 1868 an apparatus which actually transmitted musical sounds.

Many modifications were made by others during the next few years, but it was not till 14th February, 1876, that Graham Bell, a native of Edinburgh, but resident in the United States of America, patented an arrangement of apparatus which may well be considered the first of the many electromagnetic telephones. On the same day, and also in the United States, Elisha Gray patented a very similiar piece of apparatus. Gray, however, made no further effort to perfect his invention, but Bell developed his until he produced a really practical and serviceable instrument. That which he showed at Salem, Massachussets, on 12th February, 1877, forms the basis, with many and various modifications, of all modern telephone receivers. It took the form of a permanent magnet, on one end of which was placed a soft iron pole piece carrying a bobbin wound with insulated wire. In front of the pole piece and very close to it was fixed a flexible diaphragm formed of a thin soft iron disc. This disc is fixed all round the edge and is free to move in and out at the centre.

The principle on which two such telephones work when joined up by means of wires as shown in Fig. 11 is as follows:—Suppose A is used by the speaker as a transmitter, and the listener uses B as a receiver. When the sound waves consequent on speech strike against the diaphragm it bulges in and out thus disturbing the magnetic field of the permanent bar magnet.

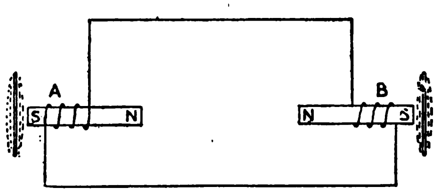


Fig. 11.

These variations in the magnetic field in turn induce varying electric currents in the coil of wire on the bobbin. The variable currents flowing along the line to B produce variations in the magnetic field there, and cause an increased or diminished force of attraction between the pole of the magnet and the soft iron diaphragm in front of it. The disc moves out and in according to the variations of current, in unison with the movements of the diaphragm at A, and thus the sound waves set up by the speaker at A are reproduced by the telephone at B.

It was in the year 1876 that Lord Kelvin introduced the telephone to the British public at the meetings of the British Associ-

ation in Glasgow, though the first pair of practical telephones were exhibited a year later by Sir William Preece at Plymouth. Lord Kelvin stated at one of the Glasgow meetings that he had heard in Philadelphia, Shakespeare quoted through an electric wire by means of two of Graham Bell's telephones which he then pronounced to be "the greatest by far of all the marvels of the electric telegraph."

The telephone as developed by Bell acts splendidly as a receiver because it is capable of responding to a current of $6 \times 10^{\cdot 13}$ of an ampere; but when used as a transmitter to generate currents sent to the line, these currents are so small as to give very unsatisfactory results over long lines. It was therefore very early felt that some other method must be devised for transforming a greater percentage of the energy of the voice into electric currents. Indeed within a few months afterwards Edison used a transmitter which was based on the fact that the resistance of carbon varies under varying pressure. This transmitter he placed in the primary of an induction coil. The result was, louder and more marked effects in the receiving instrument placed in the secondary circuit of the induction coil. See Fig. 12.

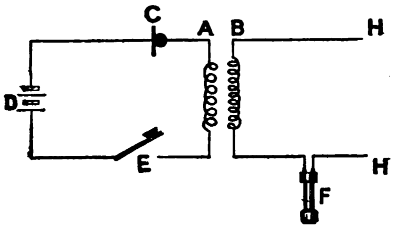


Fig. 12.

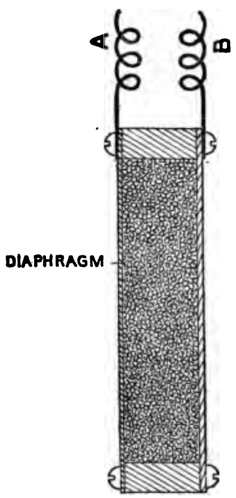


Fig. 13.

In 1878, Professor Hughes introduced an instrument which he called a microphone, on which have since been based with various modifications the best modern telephone transmitters, just as the best modern receivers are based on Bell's instrument. It depends on the principle that the electrical resistance between two surfaces varies with the looseness of the contact between them. The most important modification introduced on Hughes' transmitter was that by Hunnings in the same year, when he used granules of carbon in place of carbon

rods, thus giving a greater multiplicity of contacts and consequently greater variations (Fig. 13). The granular carbon transmitter is *the* transmitter of modern telephone practice.

The telephone, which of itself is a marvel of simplicity, has become involved in a network of considerable complexity known as the exchange system, through which intercommunication may be obtained between users. In the earlier stages of telephony the accessory apparatus was based on telegraphic usage. The real germ from which the development of the telephone switchboard springs is perhaps that represented by the patent of the Universal Jack Knife switch granted to Mr E. E. Scribner on November 29, 1879. The first telephone exchange in this country was that opened with ten subscribers by the Edison Company at 6 Lombard Street, London, on 4th September, 1879, and the second was that of the Bell Company at 36 Coleman Street, London. The switchboards used were of two different types; the one a plug board where connection is completed between vertical and horizontal bars by means of a plug only, the other a cord board where suitable plugs are placed in spring jacks which form the terminals of the various lines. In both cases electro-magnetic indicators were used. The cord board is the one most in use now. This is due, not to its greater efficiency, but to its greater flexibility, and more especially to the fact that this type of board can be more concentrated, and small occupation of space is of great importance when large numbers of lines have to be dealt with. The rapid increase of subscribers desiring connection with each other very soon led to an important development in switchboard design. An operator cannot attend to more than a limited number of subscribers' calls, and when several operators had to be employed, the difficulty of how to connect a subscriber calling on one section to a subscriber whose line was on another section was a very serious one. One method of overcoming this difficulty was to provide a number of circuits from each section to every other section by means of which a subscriber's line may be extended or transferred from one to the other. But in large exchanges, the delay introduced by the additional operation and the necessity for providing an abnormally large number of such circuits between any one section and each of the other sections rendered such a plan very soon unworkable. What was really required was that each operator, although only attending to the calls of a fixed number of subscribers, should be able to make

connection with all other subscribers on the system without requiring assistance.

This is effected by means of the multiple switch, the principle of which will be readily understood from Fig. 14. Each section is arranged for a certain number of subscribers, sufficient to require the attention of three operators. Each of these sections is fitted with switch springs to accommodate the whole number of subscribers to the exchange. The several lines are taken consecutively through each section, but at only one is there an indicator by which a subscriber can gain attention. Thus each operator, though attending only to the requirements of a certain number of calls, is able by means of switch springs to put a subscriber directly into communication with any other subscriber. For instance, if subscriber 2, whose indicator is on section I., wishes to speak to subscriber 5, the operator at section I. simply

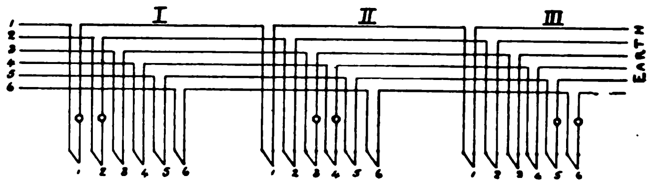


Fig. 14. PRINCIPLE OF MULTIPLE SWITCH.

connects 2 to 5 by means of a pair of switch plugs and a flexible conductor. If subscriber 5 wishes to speak to subscriber 2, then the operator at section III. would make a similar connection.

The Western Electric Company early introduced the multiple switchboard under patents dated November 1879 and June 1883. Its development has been continuous with the increasing telephone business, and while exchanges having a capacity of 6,000 lines were considered large ten years ago, we now have them at work with 15,000 lines. And there are proposals to build them up to 20,000. Such large multiple switchboards are rendered possible by improved designs in the spring jacks, making a reduction in their size possible.

The apparatus designed for the purpose of calling the attention of the operator has undergone many changes and has assumed many forms. The earlier forms were generally electro-magnets with a small shutter which was released and dropped when the electro-magnet was actuated either by direct battery current or by alternating current from a magneto-generator. This was an indica-

tion to the operator that the subscriber whose number the shutter bore on its face, was calling.

Later Mr. Frank Shaw of New York introduced what is known as the call wire system. In this system indicators on the individual subscriber's lines are dispensed with, and in place of these a second wire known as the call wire is used which is common to a group of subscribers' telephones. By means of a key provided at each telephone the subscriber can bring his telephone on to the common wire and make his wants known to the operator at the exchange who is constantly listening on the line.

One of the more recent is the central battery system so called from the fact that the current required both for signalling and for speech between subscribers is provided from one common battery situated in the exchange. In America this is generally recognised as the best, and is the system which is now being largely adopted in our own country by the National Telephone Co., the Post Office, and some of the municipalities. In it the method of operating, so far as the subscriber is concerned, is reduced to the utmost simplicity. To call the exchange it is only necessary to lift the telephone off the rest, and the act of replacing it when conversation is finished clears the line. The signal to the operator takes the form of a small incandescent lamp which is brought into circuit by a relay. The lamp, while giving a clear indication, takes up a very small space on the switchboard, as its diameter is less than one quarter of an inch. This in large exchanges is an important feature. The expense in maintenance of these lamps has been found to be very little, and their life is so good that they give no trouble. The operator having learned the number required by the caller, rings up this number, if not already engaged. On getting a reply the two are put in communication. In front of each pair of plugs there are two electric lamps as clearing signals, and these light up as soon as the subscribers hang the telephones on the instruments. The lighting of the two lamps is thus a signal to the operator to clear the lines. No ring off signal is necessary.

The existence of systems of duplex and multiplex telegraphy increasing the carrying capacity of the telegraph circuits naturally turned attention to duplex telephony. Balancing an artificial line against the real line, as in the differential duplex telegraph, is impracticable. But a modification of the bridge method was devised and patented by Mr Frank Jacob in 1882. Fig. 15.

A and A^1 are two telephones arranged as shown, R_1 and R_2 being resistances forming the arms of the bridge. A similar arrangement exists at the distant station B. The speaking currents from A do not affect the telephones A^1 and B^1 owing to there being no difference of potential due to them at the points where A^1 and B^1 are connected to the line wires. Thus A speaks to B independently of A^1 and B^1, on the other hand by making the resistance of the telephones A^1 and B^1 small compared with the resistances R_1, R_2, R_3, R_4 in the arms of the bridge the greater part of the speaking currents from say A^1 circulate via the line and B^1. Similarly when B^1 speaks the currents traverse the telephone A^1. The method was tried, but mainly in the attempt to superimpose a telegraph circuit on a telephone loop.

In later practice, however, Jacob's method has been superseded

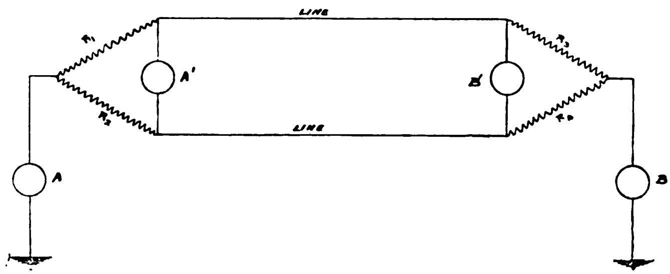


Fig. 15. DIAGRAM OF JACOB'S SYSTEM OF DUPLEX TELEPHONY.

by a plan referred to by Sir W. H. Preece as of American origin. Two trunk circuits are selected, which follow the same route, being preferably on the same arms of the poles, and alike in conductor resistance. Each of these trunks is terminated in the secondary winding of a transformer or induction coil. From the centre of each secondary winding a connection is taken, as shown in Fig. 16, to form the superimposed circuit. The latter thus consists of a circuit made up of the two wires, taken together of each trunk circuit. The speaking currents in the superimposed circuit thus divide equally on the two wires of each trunk, and consequently do not affect the speaking on these trunks. Three conversations can be carried on simultaneously.

Up to the present time the operation of superimposing has been confined to trunk circuits less than fifty miles in length. For such distances the system works admirably.

The sound waves produced by speech are exceedingly

complex and therefore the conditions necessary for the transmission of the electric currents varied by them to give minimum distortion and minimum attentuation are also very complex. [König's manometric flames were exhibited showing different configurations for different vowels and even for the same vowel at different pitches.]

Thus the problem of transmitting the currents due to these complicated wave motions without affecting the different components unequally is not easy of solution. We have to take into account the following factors:—resistance, inductance, leakage, capacity, frequency, and therefore indirectly wave length. The frequency of the vibrations range between 200 and 700. Resistance and capacity tend to attenuate the waves, and so make the strength of the current feebler and feebler as the distance increases. If, however, coils

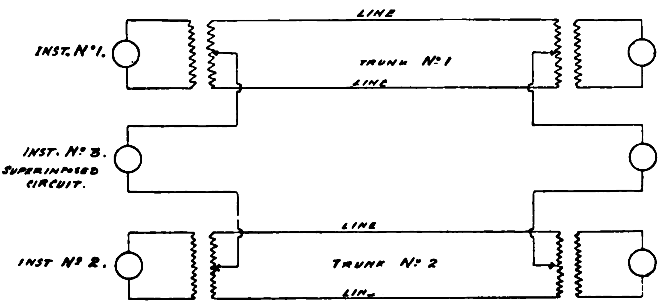


Fig. 16. PRESENT METHOD OF DUPLEX WORKING ON TRUNK CIRCUITS.

of inductance are put within one wave length, it has been shown mathematically that the waves would be transmitted distortionless if the number of coils were so spaced that between 7,000 and 13,000 were passed by the wave in one second. This would involve about one or two coils per mile. Professor M. I. Pupin proposed the construction of such loaded circuits both for aerial wires, and for cables, and the Bell Company of the United States have several such circuits in actual use.

Figures 17 and 18 are taken from a paper by Dr Hayes read before section G of the St. Louis International Electrical Congress, 1904. In both figures abscissae are distances and ordinates strengths of currents in terms of the initial unit current. Fig. 17 represents a cable circuit with a wire 0·0359 in. diameter. The capacity was 0·068 microfarad per mile, and the added inductance amounted to 600 millihenrys per mile. Curve 1 of this figure

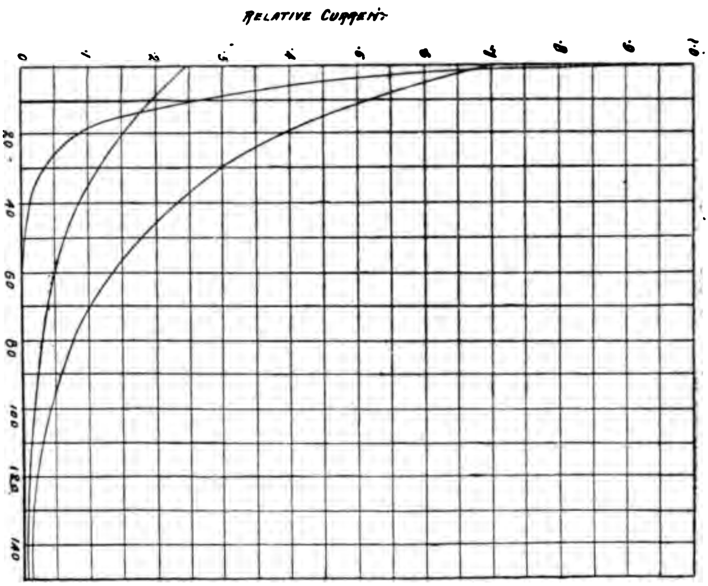


Fig. 17. LENGTH OF LINE IN MILES.

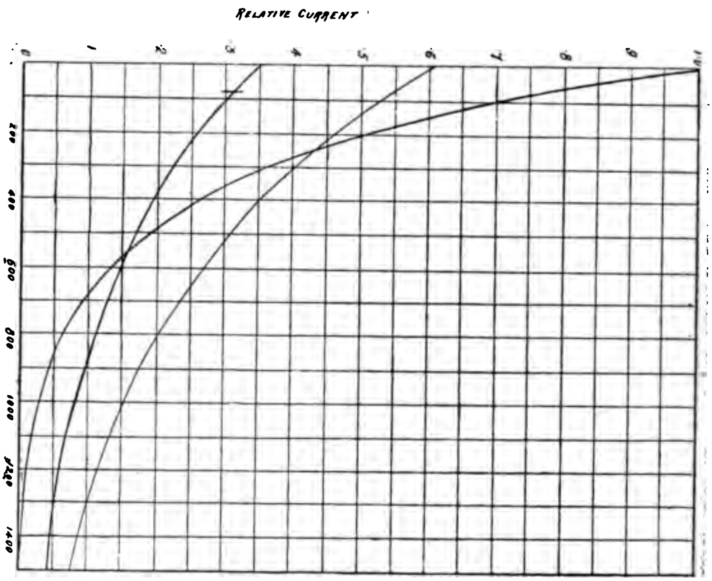


Fig. 18. LENGTH OF LINE IN MILES.

gives the current when the circuit is unloaded; curve 2, when the circuit is loaded uniformly; and curve 3 when the inductive load tapers towards both ends. In every case speaking is more distinct on the unloaded line for short distances, but for distances above 10 miles, the loaded circuit gives much more distinct speaking.

Fig. 18 gives similar curves for an aerial circuit of copper wire weighing 435 lbs. to the mile. The added inductances amounted to 100 millihenrys per mile. Curves 1, 2, 3 have similar meaning for this figure. Hence the reduction of attenuation that can be obtained by the introduction of loading coils on air line circuits is less than can be obtained on cable circuits. This no doubt is due to the relatively small inductance and large capacity of cable wires, and small capacity of aerial wires. On the other hand there is not "the same improvement in the quality of transmission on a loaded circuit as compared with a similar circuit unloaded, as is found between loaded and unloaded cables. Initially, open wire circuits are practically free from distortion, whereas the distortion on cable circuits of long length is considerable. The addition, therefore, of loading coils to aerial circuits, cannot be expected to effect any improvement in the quality of transmision, whereas in the case of cables the introduction of the additional inductance renders the circuits practically distortionless and effects a marked improvement in the clearness of transmitted speech."

Commercially the development has been rapid in all countries. Even taking our own country, which is often held up to obloquy in this respect, there has been a widespread and gratifying development. As has been mentioned the first exchange was opened in London, in September 1879, with ten stations. In 1888, London had 4,900 subscribers, with 5,150 stations and about 1,400 private renters. At the present time, including the National Telephone Company and the Post Office systems, it will have about 100,000 stations connected. The growth all round in the provinces has kept pace with that of the Capital. There is no town of any importance in the British Isles which is not in telephonic communication. Connection has also been established for some years with the Continent through the London-Paris wire, speech over which is wonderfully good and clear. A very striking indication of the growth of telephone business is given by a comparison between the number of stations connected on the National Telephone Company's system ten years

ago and now. The increase has been from 80,000 stations in 540 exchanges to 300,000 in 1,095. It is estimated that the number of messages over this system between subscribers reached last year the enormous sum of 938 millions. In addition to the N. T. Co. system we have that of the Post Office, and a number of Corporation systems of which that in Glasgow is not the least.

Looking at the capital invested in the telephone business we find that it has risen from a few thousand 20 years ago, to little short of 20 million pounds sterling now. The telephone has indeed become one of the everyday necessities of commercial life. It is in this respect of greater importance even than the telegraph, as may be seen by comparing the 938 million messages of the one with the 84 million of the other, such being the numbers that passed along the wires during the past year.

The Effect of Tensile Overstrain on the Magnetic Properties of Iron. By JAMES MUIR, D.Sc., M.A., and ARCHIBALD LANG, M.A., B.Sc.

[Read before the Society, 25th January, 1905.]

THE changes produced by tensile overstrain on the elastic properties of iron formed the subject of previous research work.[1] The object of the present paper is to effect a comparison between changes in magnetic properties and changes in elastic properties.

A rod of soft iron about 85 centimetres long and 3 millimetres in diameter was annealed, and (after magnetic tests had been made), was subjected to a gradually increasing pull, the 10-ton testing machine of the James Watt Engineering Laboratory being employed. A well defined yield-point was detected at the stress of about 1,600 kilogrammes per square cm., great extension occurring at this stress without increase of load, the specimen becoming permanently stretched or overstrained. The load in this first test was not increased beyond the yield point, so curve No. 1, diagram I., may be taken as illustrating the initial overstrain given to the specimen. The curves of diagram I have been drawn by hand, but similar diagrams with accurately plotted curves will be found in the papers referred to above.[2]

The amount of extension which occurs at the yield-point in iron is a definite property of the material; it is impossible to obtain less permanent extension. Of course the load could be removed after say one-half of the extension shown in curve No. 1 had been obtained, but that would mean that only one-half of the rod had been stretched, the other half remaining unchanged.

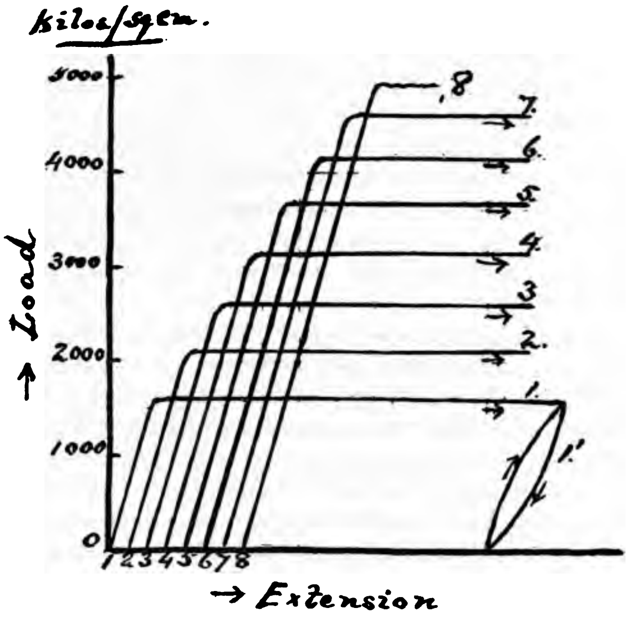
When iron has received permanent stretch it is no longer in an elastic condition, but remains for some time in what has been termed the semi-plastic state. By removing and reapplying the overstraining load, a curve of the type illustrated at 1′, diagram

[1] "On the Recovery of Iron from Overstrain," J. Muir, *Phil. Trans.*, A., 1899. "On the Tempering of Iron Hardened by Overstrain." J. Muir, *Phil. Trans.*, A., 1902.

[2] See for example, pp. 18, 19, 28, *Phil. Trans.*, A., 1902.

I., could be obtained. This curve No. 1', shows hysteresis in the relation of load to extension, and does not exhibit the phenomenon of the yield-point. To effect recovery from this temporary effect of overstrain, the specimen was heated for a few minutes to a temperature of about 100°C., and on again testing the material a well-defined yield-point was obtained at the higher stress of about 2100 kilos. per sq. cm. Curve No. 2, diagram I, illustrates the elastic condition of the material which had been overstrained

— Diagram No. I —



by the passage of the primary yield-point and then warmed to effect recovery from overstrain.[1] After this second overstrain the material was once more in the semi-plastic state, so the specimen was again heated for a few minutes to about 100°C., and on testing once more, a yield-point was obtained at the still higher stress of about 2600 kilos. per sq. cm., as is shown by curve 3, diagram I. This process of overstraining and effecting recovery from overstrain was repeated 7 times, the yield-point being raised each

[1] All the curves of diagram I should start from the same origin, they have been displaced to avoid confusion of the curves.

time by approximately the same amount, and the extension which occurred at each yield-point being approximately constant. The amount of extension which occurred at a yield-point was about $1\frac{1}{2}$ per cent. of the length, so that the rod had been elongated altogether by about $10\frac{1}{2}$ per cent. There was, of course, a corresponding diminution in cross sectional area; this has been allowed for in diagram I, and in all the magnetic curves about to be described. On applying load for the 8th time a neck began to form on the specimen at the high stress of 4900 kilos. per sq. cm., and fracture would have supervened had not the load been immediately removed.

Magnetic tests were made on the same soft iron specimen whose elastic properties are illustrated by diagram No. I, when in each of the elastic conditions illustrated by the curves of that diagram.

The ordinary magnetometric method was employed, the rod being placed in a long coil through which a varying current was passed; the magnetising force (H) was measured by the strength of the current and the intensity of magnetisation (I) induced in the iron by the deflection of a magnetometer needle suitably placed near one end of the coil.

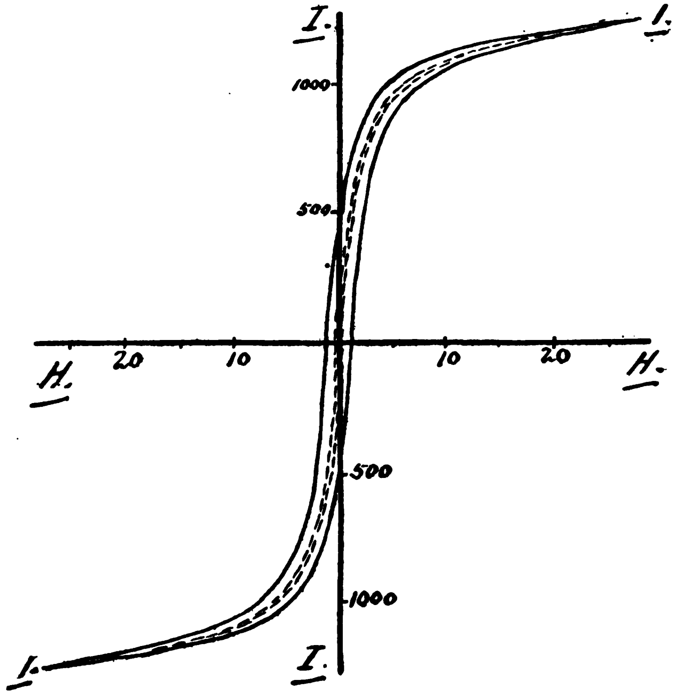
The full curve of diagram II is the I-H curve for the iron when in the annealed condition before overstrain, that is when in the elastic condition illustrated by curve 1, diagram I. The dotted curve of diagram II was obtained by tapping the specimen while in the magnetising coil, before taking a magnetometer reading. The well-known magnetic characteristics of soft iron are all clearly shown by diagram No. II, the first portions of the curves (the portions which start from the origin), have not been plotted in order to avoid confusion. The curves rise steeply and turn over abruptly towards a saturation value for I. There is very little hysteresis loss (measured by the area of the loops), and tapping practically obliterates all trace of hysteresis.

The next magnetic test was made with the object of detecting magnetically the difference between the semi-plastic state of the material immediately after overstrain and the elastic condition after recovery from the temporary effect of overstrain; but with soft iron no difference was detected in the magnetic curves (either tapped or untapped) obtained for the two conditions of the material. With a specimen of steel, however, which showed much greater hysteresis loss, a distinct though small hardening effect was

magnetically detected. It seems then, that recovery from overstrain, although producing a very marked change in the elastic properties of iron produces only a very slight effect on the magnetic properties.

The main curve (No. 2) of diagram III is the I-H curve for the soft iron specimen in the elastic condition corresponding to curve 2, diagram I. This curve shows that the least permanent

—Diagram No. II.—



stretch which could be given to the iron had a large effect on the magnetic properties. All the characteristics of overstrained iron are clearly shown, the iron has been magnetically hardened, its retentiveness diminished, and its coercive force increased.[1]

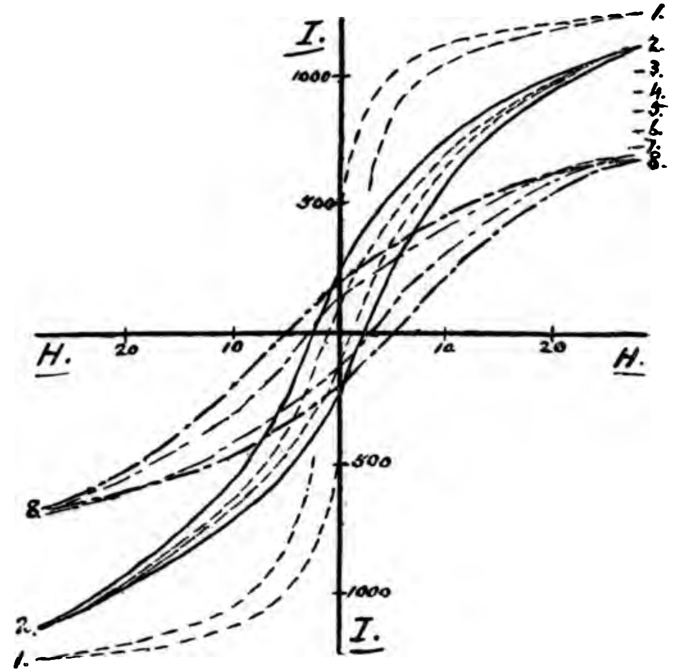
The changes produced in the magnetic condition of the specimen by the further overstrains, illustrated in diagram I., may also be seen in diagram III. The dotted curve (No. 8) corresponds to the elastic state illustrated by curve 8, diagram I. The

[1] Ewing, "Magnetic Induction in Iron," § 66.

magnetic curves for intermediate conditions may readily be imagined from the numbers 1 to 8 marked on the top right hand corner of diagram III.

These experiments then have shown, that whereas all the

— Diagram No. III. —

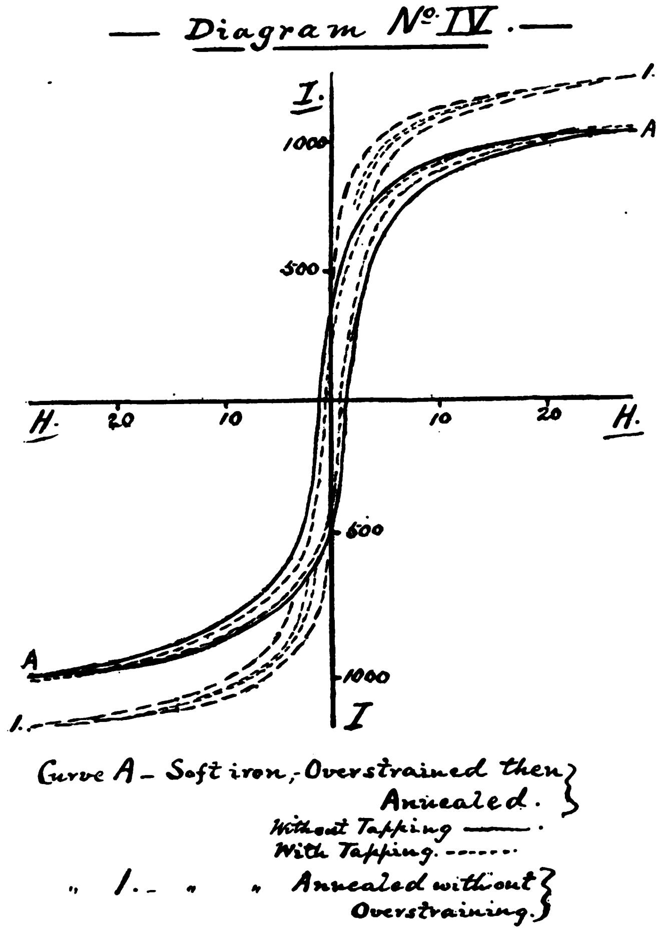


Curve No. 1. — Soft Iron — annealed.
" " 2. " " — slightly overstrained.
— Without tapping —
With Tapping ----
" " 8. " " after 7 overstrains.

overstrains illustrated in diagram No. I had practically the same effect on the elastic properties (the yield-point being raised by the same amount after each overstrain), the changes in magnetic properties were largely produced by the first small permanent stretch; subsequent overstrains produced gradually diminishing effects.

The effect produced by tapping was also found to become less and less as the material was hardened by overstrain, but even in the hardest condition attained, tapping was found to produce a measurable effect, as is shown by curve No. 8 of diagram III.

Finally the overstrained specimen was annealed and the curves



marked A in diagram IV give the I-H curves (tapped and untapped), which were then obtained. The return to the annealed condition of material is very marked; we have again the steep rise and the abrupt change in direction. It will be noticed, however, that while saturation of the iron practically occurs with

the same magnetising force, the saturation value of the magnetisation induced is distinctly lower than that obtained with the original material annealed, but without any previous overstrain other than that which may have been given in the manufacture of the rod. Further experiments are contemplated on the effect produced by annealing after overstrain has been given, but it may be of interest to refer to the fact recorded in earlier research work,[1] that thoroughly annealed iron hardened by stretching, and then re-annealed, may assume a softer elastic condition than can be attained by annealing without overstrain.

Other experiments using different qualities of iron and steel were made in the course of this research work, and it may be of interest to record one of these experiments. Diagram V shows the I-H curves (tapped and untapped) obtained with a certain mild-steel rod. The curves marked A show the condition of the material as supplied. There is much greater hysteresis loss than in the case of soft iron, and tapping has comparatively little effect. The specimen was heated to redness and hardened by 'quenching' in cold water. The curves marked B in the diagram show the great change produced by the 'quenching.' Steel hardened by 'quenching' may be regarded as a different material from annealed steel; the microscope reveals an entirely different structure in the two cases.

In conclusion, it may be considered desirable that something should be said as to the theory underlying the effects considered. Ewing has applied the molecular theory of magnetism to the effects of stress on the magnetisation of iron; and by supposing that overstrain (in Professor Ewing's words) "resolves a structure which is relatively homogeneous and continuous into one which may be described as a patchwork of more or less distinct molecular groups,"[2] the effects we have been considering may, in a manner, be explained.

Now, we know, as the result of microscopical examination, that a bar of iron is composed of a great many crystalline granules which have been formed by a gradual growth from a number of nuclei. When iron solidifies, crystals form here and there throughout the molten mass, and a gradual growth takes place round each crystal, until neighbouring growths interfere with one another,

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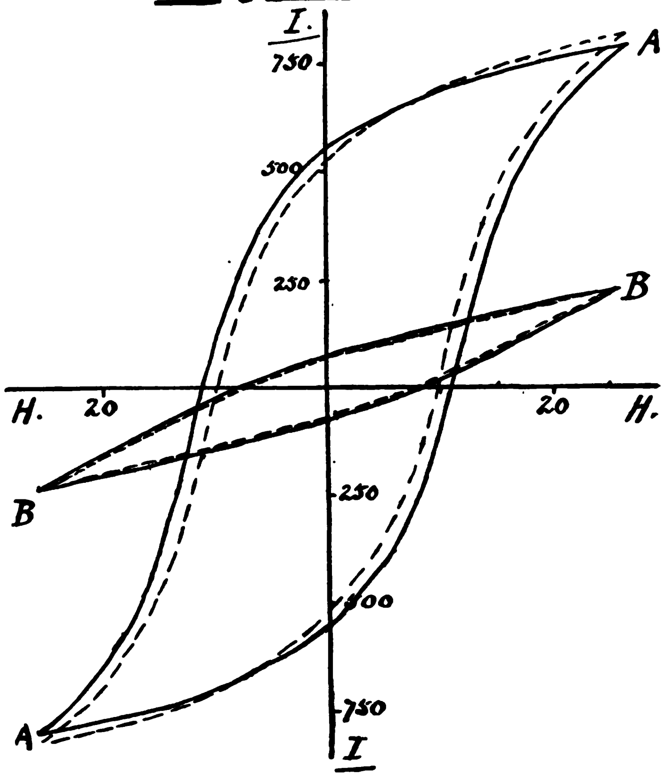
[1] See diagrams, pp. 28, 30, *Phil. Trans.*, A., 1902.

[2] Ewing "Magnetic Induction in Iron and other metals," § 185.

and form the junctions of the crystalline granules. Similarly when the temperature of recalescence is attained in a cooling mass of iron, that is the temperature at which magnetic properties appear,—a gradual growth may be supposed to take place round

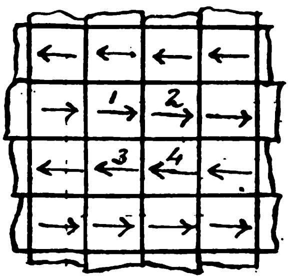
— Diagram No. V. —



A – Mild Steel Rod – as supplied.
B – " " " after quenching from a red heat.
Without Tapping ——— .
With Tapping - - - - - - .

magnetic centres. An elementary magnet may be supposed to appear in some one crystal. (No 1 in the sketch). The magnet must have freedom to turn in the crystal so that when an adjoining magnet forms, the two will aline themselves as shown. Now

suppose magnets 3, 4, etc., to form *in turn* round No. 1, and it is evident that the result will be just such a regular arrangement of magnets as will exhibit under magnetising force a behaviour analogous to that of annealed iron.[1] Now suppose the iron to receive an overstrain. The microscope has shown that permanent set takes place, not by the relative motion of the granules in the iron, but by the shearing of the individual granules, sliding taking place along a great many cleavage planes of a single granule. This sliding gives rise to the appearance of what have been termed slipbands[2] in metallography. Now referring to the accompanying sketch it is evident that a slip of molecular dimensions along a vertical cleavage plane would suffice to upset entirely the regular arrangement on each side of that plane—a N pole would be brought opposite a N pole. Thus the arrangement which necessarily results when the molecular magnets form one by one round a central magnet, will be broken up by overstrain into a "patchwork of more or less distinct molecular groups," and this will suffice to explain in a manner the fact that a slight overstrain produces a large effect on the magnetic properties of iron.



The work which has just been described was carried out in the Physical Laboratory of the University of Glasgow, and the authors have pleasure in acknowledging their indebtedness to Professor Gray who has done much suggestive work bearing on the internal structure of metals.

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[1] See Ewing's "Magnetic Induction in Iron," § 174.

[2] Ewing and Rosenham "On the Crystalline Structure of Metals, *Phil. Trans.*

Biographical Sketch of the late James B. Russell, M.D., LL.D., by JOHN BROWNLEE, M.A., M.D., Physician Superintendent, Glasgow Fever Hospital, Belvidere.

[Read before the Society 22nd February, 1905.]

DR JAMES BURN RUSSELL was born in Glasgow in the year 1837. He however passed his boyhood in Rutherglen, being brought up in the house of his grandfather, a man of high ideals and great strength of character, qualities inherited in a marked degree by his grandson. He was educated first in the High School of Glasgow, and afterwards in the University, in both of which he took a distinguished place. He graduated Bachelor of Arts in 1858, and for a time assisted Lord Kelvin (Sir Wm Thomson) when he was superintending the laying of the Atlantic Cable. He graduated Doctor of Medicine and Master in Surgery in 1862, after taking throughout a high place in his Medical Classes.

He then acted as House-Physician in the Royal Infirmary and in the City Poorhouse until he was appointed, on the advice of Dr Sir Wm Gairdner, Physician Superintendent of the new Fever Hospital in Parlimentary Road. In 1872, when Dr Gairdner resigned his position of Medical Officer of health, Dr Russell was appointed his successor, and retained this position until 1898, when he became Medical Member of the Local Government Board of Scotland. During the period that he was Medical Officer of Health for Glasgow however, he performed the chief part of his life work by which he gained that reputation which is common knowledge.

In 1885, The University of Glasgow conferred on him the honorary degree of LL.D.; in 1895, he was awarded the Stewart prize for his researches on "The Origin, Spread, and Prevention of Epidemic Disease," by the British Medical Association; in 1898, he was selected as one of the members of the Royal Commission on the disposal of sewage; in 1899, the Royal College of Physicians of London, in making the first award of the Bisset-Hawkins Memorial Medal, chose Dr Russell as the recipient, in recognition of the services he had rendered in promoting Public Health. He was also an Honorary member of several foreign Hygienic Societies.

His connection with this Society was long and honourable. He was chosen first as President of the Sanitary Social and Economy Section, then President of the Society itself, and on his removal to Edinburgh, was placed on the roll of honorary members.

His public interest found a wide field in Glasgow. In his College days he was one of the first volunteers, and later on, though his activities were mainly confined within medical circles, he held many important positions. He was one of the founders of the Clinical and Pathological Society of Glasgow, and was for many years its Honorary Treasurer; he was a Director of the Central Dispensary, and of the Glasgow Sick Poor and Private Nursing Association; while his labours on the Boards for both the Royal Hospital for Sick Children and the Western Infirmary are well known to all interested in philanthropic work in Glasgow.

Practically the whole of Dr Russell's life was spent in the service of Glasgow. From the time when he was appointed to take medical charge of the first municipal hospital in Scotland, till the time when he left to become Medical Member of the Local Government Board in Edinburgh, he was associated more or less with all the sanitary reforms which have been carried through in the City.

In 1865, when he took up the duties of Medical Superintendent of the Fever Hospital in Parliamentary Road, such hospitals were not regular institutions. Methods of working were on trial, and all details of management had to be thought out for the first time. A perusal of the series of reports which he issued regarding the administration of this hospital, shows not only with what care he considered every detail, but re-creates a world of past difficulties besides which present troubles appear trivial. Nursing in the modern sense of the word did not exist. Out of thirty-five nurses engaged during the first year, eighteen were dismissed for drunkenness, inefficiency, or dishonesty. The reform of this obtained his first attention, and the result of his experience is found not only in the pamphlet which he issued at this time in support of the necessity of the systematic training of nurses, who should be both capable in their profession and trustworthy women, but also in the interest which he continued to take in this matter till the end of his life. But though Dr Russell devoted so much attention to the working of the institution, he did not fail to be as exacting in the medical part of his duties. His study of the use of alcohol as a stimulant in Typhus Fever, is a monograph which is even yet

a valuable guide, and marked at the time yet another stage in the destruction of the doctrine that alcohol is one of the chief foods suitable for persons suffering from the continued fevers. His study of smallpox with reference to vaccination is still referred to, and was illustrated by a diagrammatic method of representing statistics which has since been extensively adopted, while his observations on the use of chloral hydrate as a hypnotic were also of importance at the time.

When Dr Russell became Medical Officer of Health for Glasgow, some of the main steps towards the foundation of a proper department of Public Health had already been taken. Sanitary reform in Glasgow had taken origin seriously a number of years before this with the passing of the Corporation Water Works Act in 1855. The first attempts, however, to deal with epidemic disease on a permanent footing began in 1863, with the appointment of Dr Gairdner as Medical Officer of Health for Glasgow. Under his influence some of the chief measures which have changed Glasgow were undertaken—the City Improvement Act was passed, the Committee on Health in the Town Council was formed, a Sanitary Inspector was appointed, new hospitals were opened at Parliamentary Road and at Belvidere, and a Reception House and a Sanitary Washing-House established. The great work, however, of making these reforms serve their purpose lay to Dr Russell's hand almost untouched. From the first he took a modern and broad view of his duties, bringing to bear all the scientific advances inaugurated by Pasteur and Lister to establish better protective means against the spread of disease. The channels by means of which epidemic diseases are spread, were not nearly so well known then as now. Epidemics caused by milk contamination were only surmised, yet one of the first reports to the Local Authority was an outbreak of Enteric Fever in Parkhead, which he traced and conclusively proved to be due to the infection of the milk supplied. This outbreak was one of the earliest assigned to this source of infection, and it affords a good example of that independence of tradition with which Dr Russell was wont to act. From this time onwards, his attention was unceasingly directed to the prevention of epidemics—he advised the erection of a new Smallpox Hospital, as that in Parliamentary Road did not afford sufficient isolation; he continued the crusade against Typhus Fever, which speedily resulted in the practical extermination of that disease; he took steps to

effect the much more perfect isolation of persons suffering from Zymotic Diseases in general, both at home and in hospital, for the first time paying special attention to those affecting children; he made arrangements with the School Board of Glasgow whereby the spread of infection by schools was greatly limited; he delivered lectures on the prevention of infectious diseases, and pled for their compulsory notification; he issued tracts summarising the law on infectious disease, and giving hints on the management of Scarlet Fever, which were freely distributed; he made arrangements to trace the vaccination defaulters—in fact, during his first ten years of office, he brought the administration of epidemic diseases very nearly to the point at which it remains at present.

A milk epidemic afforded a special weapon which he did not hesitate to use It was here that he could most forcibly present his case for the sanitary control of dairy farms and dairies, for a dairy farm in the country is merely picturesque until it has spread death among the inhabitants of a city. From an early time Dr Russell, by forcing upon the Glasgow dairymen the necessity of choosing that the farms from which they took their milk supply should have a certain standard of cleanliness, and by advising institutions to take their milk from none but the best equipped farms, brought the "monetary lever" to bear on country sanitation. His series of reports on the spread of both Enteric and Scarlet fevers by means of milk are so many trenchant pleas for better administration of the Public Health Acts. One of the most interesting of these concerned an epidemic which attacked the hospitals alone. In this he did not hesitate to arraign the Board of Supervision, composed at that time chiefly of lawyers, for the lax oversight which it exercised over the sanitary administration in the country. Milk supply remained to the end a matter of very special interest to Dr Russell, for not only did he draw up for the Local Authority a summary of the sanitary requirements of a dairy farm, but he specially addressed the farmers themselves on the subject, and laid before them a carefully prepared synopsis of the manner in which Glasgow had been specially infected by milk with zymotic diseases from the time he had been responsible for the oversight of the health of the City.

When Dr Russell was appointed Medical Officer of Health in 1872, the City Improvement Trust was busily engaged buying and destroying much of the household property in the slums which had made Glasgow so easily the victim of epidemic

disease. This work had from the beginning Dr Russell's complete sympathy, and he not only followed its operations closely, but, making a careful survey of its effects on the displaced population, he showed that the people evicted from dilapidated and unhealthy property for the most part removed into better houses of somewhat higher rent, and in many instances into houses with an accommodation considerably superior to that of those from which they had been displaced. He emphasised, however, with no uncertain voice, both at this time and continuously, that the Improvement Act was in reality a half measure, and that there was an urgent necessity for the immediate enactment of Building Regulations if Glasgow was to obtain benefit at all commensurable to the expenditure which was taking place; a reform for which, however, the City had to wait nearly twenty years.

Coincidently with these improvements, he supervised the enforcement of the Clauses of the Public Health Act of 1865, which applied to like conditions, and thus brought about a considerable improvement in the state of much of the lower class property. This was not accomplished without numerous appeals to the law courts; and one of these decisions, which Dr Russell himself considered of first importance, was that in which it was decreed that dark and unventilated lobbies constituted a nuisance within the meaning of the Act. From the time when this was determined, however, there was a considerable period during which little progress was made in the destruction of old Glasgow. The financial depression which came on during the latter part of the decade of the seventies rendered the operations of the City Improvement Trust a matter of considerable difficulty. It was impossible to dispose of the property acquired on anything like favourable terms, so that buildings purchased for destruction were temporarily repaired and remained in occupation, and thus the City itself became much the largest proprietor of unhealthy property within its boundaries. For a considerable period little progress was made, and it was not until 1889 that on the report of the Medical Officer of Health, the work of the Trust was resumed, and the last of the unhealthy wynds and closes, which had been the bye-word of sanitary reformers for three generations, were swept out of existence. With this and with the passing of the Building Regulations Act in 1892, came the consummation of objects for which Dr Russell had fought consistently during twenty years, and the ground fresh cleared for a new start.

Of his later writings, pertaining chiefly to matters of Public Health, two stand out prominently. To one of these, the Report upon the Prevention of Consumption, it is only necessary to refer, as on its publication it received a large amount of notice, and became a standard work among those who were interested in the subject. It had also a wide American circulation, and was issued as a State paper by the Government of Massachussetts. The other, the Evolution of the Function of Public Health Adminstration as illustrated by Glasgow, demands more attention. It is without doubt one of the ablest Public Health Reports in existence. The view which it gives of the conditions obtaining in large parts of Glasgow, illustrated by a well-chosen series of quotations from many pamphlets, brings up a vivid picture of the conditions of life when Smallpox, Cholera, Typhus, and Relapsing Fever decimated the City. We have now little idea what these conditions implied, and there is no better description to be found within a short compass than that given in "The Evolution." From the beginning of the century until 1894, the whole history of Public Health Adminstration in Glasgow is vividly written, the very details and figures in place of exciting a feeling of weariness, but serving to make the picture more clear. Practically every problem which affects the health of the City is discussed and displayed in all its relationships. From the first pages, when he portrays the overcrowding and ill-housing of the poor, to the last pages where he comments on the damage we suffer from our polluted and smoke-laden atmosphere, the book never loses interest. In fact, it must ever remain for the City of Glasgow one of its chief historical documents.

The most important part of Dr Russell's work, to my mind, however, is the influence which he exerted in raising the sense of social responsibility towards those less fortunately situated in the struggle of life. Dr Russell had the great advantage of being brought up in the country, thus mixing with, and knowing intimately from childhood all classes of persons, their customs, and their views of life, and in consequence had developed that sense of personal sympathy with mankind in general which as a rule can only be acquired in youth. Town life separates, in the most artificial manner, those who belong to different grades of society. From youth, sympathy with distress is exercised from an external standpoint, which unfortunately savours largely of patronage. No real attempt, for the most part, is made to con-

sider the conditions of the poor, not as difficult problems to be solved and settled according to the type of mind of the thinker, but as matters pertaining to human life.

In his earliest papers, many of which were read before this society, he was never tired of emphasising the difficulties which beset life in the poorer parts of the City. These papers are never concerned with hasty generalisations, but contain careful and elaborate accounts of the actual conditions in which numbers of persons live. The nominal subject of the paper is in general but the text, and he invariably extends this so as to present the matter from many unexpected points of view, and so form a social survey in which little escapes his attention. The life of the people, their health, their surroundings, the manner in which they are born, live, die, or are buried, how they are nursed and medically attended when ill, what virtues they have to compensate for their shortcomings, are all brought before our eyes. The two points of view are always before his mind; from the one, the hygienic, these persons constitute the slum and thus an evil to be swept away as soon as possible; from the other, the humanitarian, they are men and women brought up under circumstances of which the average person has no conception, persons to whom so little has been given that little can be expected from them. Of these papers, the one which is probably of the greatest importance as summing up the fruit of his observation and thought is "Life in One Room." There is very little that can be said on the subject which is not contained in the twenty pages of this pamphlet, in which are reviewed the conditions of life in such a house as it exists in large cities, and the whole of the disadvantages which it imposes upon the unfortunate inhabitants. Remedies he is very chary of proposing, but he insists on the protection of well administered sanitary laws, which, by enforcing a standard of cleanliness, and setting up a better standard of outward life, should render the people more easily amenable to the better influences of civilisation.

Of his work while on the Local Government Board in Edinburgh, it is more difficult to speak. Administration under the conditions of Government service is such that one man's advice being incorporated in an official decision, there are no means of telling what part he specially has played. A few points stand out, however. Judging from the reports of the Local Government Board, and the changes in its line of action, which are apparent after Dr Russell's accession to office, there seems no doubt that

his appointment heralded a more thorough administration of the Public Health Acts. All over the country there is evidence of this in various measures which seem to have been undertaken in response to stimulation from the headquarters in Edinburgh. During the last five years, for instance, the number of local fever hospitals has greatly increased. In many ways the Cumpulsory Clauses in the Public Health Acts seem to have been brought more directly under the notice of the local authorities, while more extensive advantage has been taken of those which require to be voluntarily adopted by each local authority. As all who knew him recognised, he was not the man to allow any Act of Parliament which made for good administration to remain a dead letter if he could help it.

In conclusion, throughout the whole of Dr Russell's work, we find the great general principles of hygiene always insisted on. It was useless when it had become apparent that damage to health resulted from any recognised source, to try to obscure the matter in dispute by arguing on a side issue. His end clearly in view, the certainty that the measures he advocated led to that end, it became practically impossible to turn him aside. He might halt, he might temporise a little, but his opponents found, almost without exception, their resistance useless. Not that he avoided a pitched battle, if such were necessary; and his fights over uninhabitable property, and over the condemnation of tuberculous carcases, were carried through with a regard to detail which effectually destroyed hope on future appeal to the Law Courts. His only serious defeat occurred in his fight on the interpretation of the Food and Drugs Act. Here, there is not a particle of doubt that in principle he was correct, and although it may be some time before the law comes into accord with common sense, the final victory is certain. It is easy at the present day to minimise what Dr Russell accomplished because he was a man who cared little if others obtained the credit for a long campaign, provided the victory was won, but although this is the case, all who knew him and who worked with him realised how truly his was the guiding hand which controlled the Public Health Administration of Glasgow.

Although he was, owing to health, more of a recluse than is usual in public officials, his native imagination enabled him to view life whole, and his scientific instincts and training to see it clearly. This combination of power of imagination with capacity

for scientific thought is not common, but when it exists, undoubtedly marks a fine mind, for it implies as a rule that both moral and intellectual qualities are present in due balance, and though, perhaps, it may not be best suited for moving masses of men to great issues, yet it is by such minds that much of the best work of the world is done. I might, as one who had the privilege of working with him a considerable period, make some further remarks on Dr Russell as a man, on the lovableness of his nature, or of his conscientiousness as regards the execution of his duties, but these are well known to all who knew him either personally or officially. As this is a scientific society I have tried in the preceding remarks to show how large a domain Public Health occupied in his eyes, and how much knowledge of medicine, science, and humanity he brought to bear in devising measures to improve its administration. I do not mean to suggest in what I have said that Dr Russell was the only man of his time who thought such thoughts, but throughout his long career he stood in the forefront of those who made hygienic subjects their speciality, while his critical faculty enabled him in a large measure to separate the true from the false, and thus in addition to being a light bearer himself, to be a safe pilot to those who had chosen him, while yet a young man, to guide their affairs.

The Education of the Examiner. By CHARLES E. FAWSITT, D.Sc., Ph.D., University of Glasgow.

[Read before the Society, 19th April, 1905.]

As examinations are made a test in many walks of life, it is desirable that this test should be as fair a one as possible.

The results of examinations conducted in various ways have been looked into by many educational experts and statisticians, and certain conclusions have been drawn from such investigations which do something towards guiding examiners in their task.

There are many points on which examinations may be criticised. I propose to mention only one of these—the error made by an examiner in correcting a paper, and to point out how attempts have been made to discover this error by graphical representation of the examination results. The graphical representation of examination results in certain kinds of examinations permits of other interesting interpretations and this latter subject forms the chief part of the present paper.

In the estimation of any quantity an error is made. In estimating the weight of an object by taking it in the hand the extent of the error can be found by weighing the object afterwards in a balance, but there is no such ready means at hand for comparing any examination mark with the proper mark.

Let, however, a number of examiners all correct one paper. Then there may be found some mean about which the different markings will group themselves. This mean value may be looked on as constituting the standard value of the paper.

The results of the marking of a paper by several examiners may be plotted graphically: the number of marks given is plotted along a horizontal line, and the number of examiners giving a particular mark along a vertical line. The curve obtained is the ordinary curve of error. A typical curve is given in Fig. 1.

The maximum point of the curve represents very nearly the true value of the paper. (In the case given by Fig. 1 the true value would be 50 per cent.).

The error made by an examiner in giving a mark to a paper has reference to this standard value.

It is evident that a curve of regular form as in Fig. 1 can only be obtained by employing a very large number of examiners to correct a paper. It is seldom that an opportunity presents itself of obtaining this, but the experiment when tried has given results in accordance with what theory predicts.

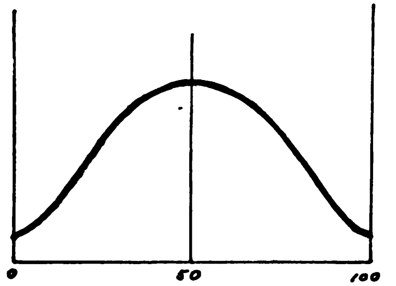


FIG. 1.

From the markings of several examiners it is possible to derive a figure which represents the probable error made by an examiner. This error varies in magnitude with the subject, but may be taken as having a minimum value of 4 or 5 per cent. The aggregate mark on a number of subjects has a smaller error than this, but may be taken as having an error of not less than 3 per cent.

If the element of chance in an examination were better known among the candidates it would lead to the encouragement of those who were unsuccessful to make a second attempt.

The errors of marking which have just been considered may be looked upon as springing from personal idiosyncrasies in regard to particular questions and in regard to the scale of marking generally. There are other errors which have hitherto been supposed to be excluded, errors which arise from the changing moods of the examiner, and from the hurry which is often required to get through a large number of papers. All these different errors can to some extent be controlled by a method which was introduced some time ago in connection with the Civil Service Examinations. This brings me to the principal part of my paper, namely, the use of graphical methods in obtaining information about examination results.

A graphical method has been used to show the variations of the marking of a paper by several examiners.

Theory would suggest that the marks given by one examiner to several papers will be grouped according to the same pattern as the marks given by several examiners to one paper.

There appeared about a year ago in "Nature" **70,** 63, a paper by Mr Sargant, lately of the Civil Service Commission, on this subject. His method was to plot percentage of marks as

abscissa, and the number of candidates corresponding to any given percentage as ordinate. As, however, it is not possible to mark to such a degree of accuracy that any mark may be looked on as quite correct, it is necessary in practice to group the candidates who obtain marks within certain limits together. When plotting such results, I have found it best to group together candidates who obtain percentages as follows: 0—10 per cent., 11—20 per cent., 21—30 per cent., 31—40 per cent., thus giving ten points on the curve. Mr Sargant found that a large number of examinations gave results such that the curve may be represented by a curve such as Fig. 1. The equation to this curve is given by $y = a\,e^{-\frac{x^2}{p^2}}$. If a be increased or p decreased the form of the curve changes to one such as is represented by Fig. 2.

An elongated curve like this is an undesirable one to obtain as the candidates are not spread out sufficiently over the range of marks.

(It should be mentioned that in order to obtain regular curves it is necessary to have at least one hundred candidates).

Some years ago the Civil Service authorities began to send out to each of their examiners a specimen curve such as is given in Fig. 1, with instructions that a batch of about a hundred papers should be gone over, and if the results when plotted did not conform to the correct shape, were to be gone over again until they did.

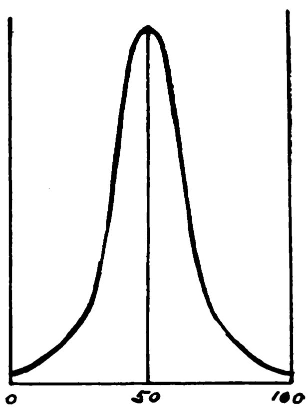


FIG 2.

The result was to ensure uniformity in the marking of different subjects, and diminish other errors made by the examiner.

To the general form of the ideal curve little exception can be taken, but it is open to question that the maximum of the curve should occur at a point representing 50 per cent. of the marks. Does it not seem reasonable that a candidate of average intelligence should be able to make a somewhat higher mark than 50 per cent., say 60 per cent.? An alteration of such a standard curve in this sense seems desirable.

I wish next to consider a special type of examination—that of the class examinations of universities and colleges.

These are examinations which serve as a means of measuring the intelligence and progress of a class, as a means of discovering ability in individuals, a means of determining the value of the teaching and of securing landing-places for portioning out a course. This style of examination finds a large place in the universities of Scotland and England, but is not found to any extent, so far as the author knows, in Germany. It is an admirable discipline for enforcing definite work for the first few years of a student's curriculum, though it will tend to discourage independence if carried on to too great an extent right through the curriculum.

Instead of dealing with a large number of men who have received instruction from many different sources, the class examination has to do with a group of students who, while possessing in a varying degree ability and working capacity, are receiving the same instruction daily.

Some eighteen months ago I happened to be looking over a class list in the University of Edinburgh, and was struck by the fact that there appeared to be a larger number of students with a very high mark, about 80%, than there were with a smaller mark, about 70%, although the number with a still smaller percentage was again higher. This might have been rather an exceptional circumstance, or it might be put down at first thought to inefficient marking. In this particular case, as in all the figures I am about to give, I think there can be little doubt with regard to the marking. Either one examiner corrected all the papers throughout a session, *or* several examiners divided the correcting at each examination, so that each examiner corrected one question throughout the whole of the papers, thus ensuring the same treatment to each candidate. The question of the observation being accidental or not could only be decided by taking the results for a number of years and looking into the marks more closely. I had some doubt as to its being worth while to trouble about the matter, but at the suggestion of Professor Crum Brown of Edinburgh University, I determined to investigate the matter with the intention of finding whether such curves have two maxima instead of the single maximum in the standard curve. The method of graphical representation was applied in the first instance to class examinations at the University of Edinburgh, and later to examinations at the University of Glasgow. The classes at these universities are

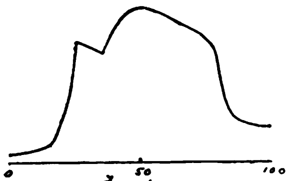


Fig 4

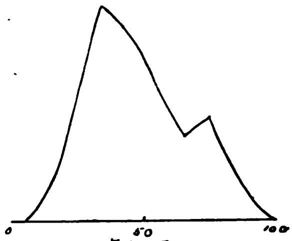


Fig 5

Fig 6

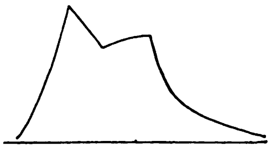


Fig 7

Fig 8

Fig 9

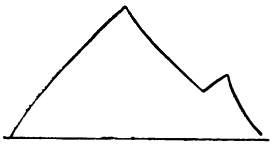


Fig 10

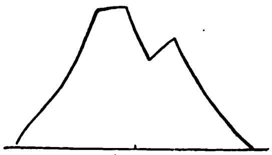


Fig 11

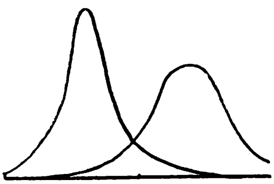


Fig 12

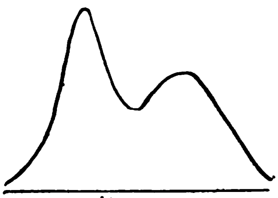


Fig 13.

usually large enough to give every opportunity of obtaining curves which are truly representative of the existing conditions.

I tried first of all to see if anything could be got out of the results of a single class examination, but the curves from such are too variable to permit of any such conclusions being drawn.

As there are usually three or more class examinations in the session, I next tried to see what results the average marks obtained in all the class examinations would give. In obtaining these results, it was considered advisable not to take into account the marks of any student who had not been present at all the examinations.

The result of a class at Edinburgh University for four successive years are given in the table below.

TABLE I.

MARKS.	YEAR.			
	1899-1900	1900-1901	1901-1902	1902-1903
0 – 10	1	3	0	2
11 – 20	10	4	7	12
21 – 30	24	31	34	32
31 – 40	47	28	53	31
41 – 50	44	39	47	42
51 – 60	29	39	31	50
61 – 70	31	35	21	41
71 – 80	15	32	26	32
81 – 90	9	11	12	14
91 – 100	5	10	3	6

A graphical representation of the results for the first year is given in Fig. 3. It will be noticed that this curve shows two maxima. The occurrence of two maxima is found in all the years given by this table (Figs. 4, 5, 6, on Plate), but the form of the curve varies considerably. Fig. 3, however, appears to represent the form of curve most frequently got from such results.

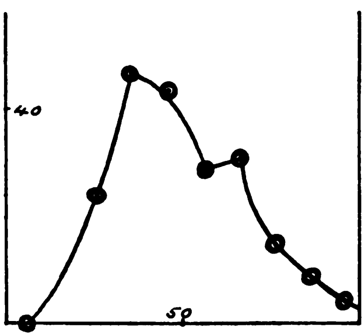


FIG. 3.

The results of another class

at Edinburgh University were examined in order to test further the occurrence of two maxima.

The results for three successive years are given in Table II., and the curves in Figs. 7, 8, 9 (see Plate).

TABLE II.

MARKS.	YEAR.		
	1894-1895.	1895-1896.	1896-1897.
0 – 10	0	0	2
11 – 20	15	5	5
21 – 30	33	34	35
31 – 40	23	26	33
41 – 50	27	22	25
51 – 60	26	22	26
61 – 70	10	19	16
71 – 80	7	17	19
81 – 90	4	9	10
91 – 100	2	2	2

The result of two consecutive years for a class at Glasgow University are next given (Table III.), and the curves representing these in Figs. 10 and 11 (see Plate), when two maxima may again be observed.

TABLE III.

MARKS.	YEAR.	
	1901-1902.	1902-1903.
0 – 10	0	0
11 – 20	11	12
21 – 30	21	19
31 – 40	25	34
41 – 50	33	35
51 – 60	23	23
61 – 70	19	28
71 – 80	13	16
81 – 90	16	5
91 – 100	3	0

As these results have not in any way been selected from a number but are given just in the order in which they were

obtained, I think it will be allowed that the appearance of two maxima in the curves for such results as have just been discussed is not accidental, but rather something which may even be expected. There are, without doubt, many class lists which will not show this peculiarity, but the fact of its existing at all requires some explanation. The explanation which is offered here I owe to a suggestion of Professor Crum Brown.

Let it be supposed that two different kinds of candidates were attending a class—say candidates of two different races. Then the examination curves if plotted separately for each of the two sets of candidates would show a single maximum, but at different percentages. In Fig. 12 two such curves are drawn. They may be represented by the equations $y=a\,e^{-\frac{x^2}{p^2}}$ and $y=b\,e^{\frac{-(x-s)^2}{q^2}}$. The equation of the curve formed by combining these two is $y=a\,e^{-\frac{x^2}{p^2}}+b\,e^{\frac{-(x-s)^2}{q^2}}$. It will depend on the relation of the constants in this equation whether the curve obtained has one maximum or two maxima. In Fig. 13 is given the curve which is formed from the combination of the two curves in Fig. 12. This curve has two maxima and is similar in form to the majority of the curves obtained from the class lists.

Although in the classes here considered, there are not two different races, there are apparently two distinct sets of students. A class of this kind may in fact be divided into a set which works and a set which does not. A student could as a rule be quite definitely classed as a worker or non-worker. The students in either group will vary in *ability* in every conceivable way, but the line of division is drawn with regard to *work.*

The curve for the workers has a maximum at a higher percentage than that for the non-workers. It will depend on these percentages and on the number of students in each group what the resultant curve will be like, but in certain cases it must have the two maxima.

This theory leads to the following idea. It appears likely that the marks of a non-worker throughout a session will gradually fall off, while the marks of the worker will either remain steady or show an increase. Hence the workers may be picked out from the others.

But in endeavouring to follow this out, I saw that it was quite

impossible to obtain any information from examination lists, as the marks of a student do not usually rise or fall steadily during a session, but vary in a most erratic fashion.

The idea may be all right, and its impracticability is due to the difficulty of setting examinations which are equally difficult throughout a session.

I trust that in what has been said, it may have been indicated that in the consideration of examination statistics, there is much that is useful and interesting to be obtained, and that the representation of these by graphical and other methods will gradually bring more light to the difficult question of making examinations a proper test in all branches of life where they are employed.

Decay of Stones in Buildings: the Cause and Prevention. By SAMUEL SMITH, Clerk of Works, Glasgow and West of Scotland Technical College.

[Read before the Architectural Section, 28th November, 1904.]

IN preparing this paper on the Decay of Stones in Buildings, I have endeavoured to keep as far as possible on practical lines. It was through coming in contact with the subject as a practical man that I was led to make inquiry, and to find out as much as I could about the causes which contribute to the decay. In presenting what, in my opinion, are the chief causes of the decay, I shall, as far as my limited knowledge of chemistry will allow me (for I do not profess to be a chemist), combine the scientific with the practical, and thus try to show as clearly as I am able what are the causes of decay; how they are brought about; and what may be done to prevent them.

The stone used in Scotland for building purposes is mainly what is termed sandstone. In some districts we find granite in use, in others whinstone, these being the stones native to the district, while in the Callander district we find the local pudding-stone largely used. The general rule, however, in the present days of railway communication, is that sandstone is the stone used for buildings throughout the country.

Sandstone has been defined by one writer on the subject, as consisting "of quartz grains—commonly called sand—bound or cemented together into a more or less compact mass, the cementing material consisting of such substances as the carbonates of iron, lime or magnesia, clay and silica." It does not come within the scope of this paper to consider how the cementing material got among the sand, it being sufficient for us to know that it is there, and that the different kinds of cementing material have each qualities which are very important to us in the consideration as to whether a stone is a good weather stone or not, as I will endeavour to show later on.

In country districts, until recent years, the building stone in ordinary use, was quarried locally. In some cases good stone

was got, and in others bad. Some of the stone that was soft when quarried, on being exposed to the atmosphere became firm and hard, proving itself to be as good a weather stone as any of the harder varieties. On the other hand some of the stone that appeared to be of good or fair quality when newly quarried showed signs of decay after being built.

The cause of this decay, in a great many cases, may be attributed to the cementing material of these stones being of a natural clayey nature which is susceptible to frost. If there be any clay in the stone the frost seizes upon it, and acting upon the moisture it contains, the clay swelling up, opens up the stone, in some cases bursting it asunder, thereby causing disintegration.

The cause of the increase of hardness of stones that become air-dried is attributed to the action of the carbonic acid of the atmosphere, and the process may be thus briefly described. In every stone, when it is newly quarried, there is a certain amount of moisture or natural sap. In many cases where the original binding material of the stone is of a feldspathic nature, this moisture has in solution a quantity of one of the alkaline silicates. As the sap gradually dries out, this soluble silicate comes to the surface of the stone, where by the action of the carbonic acid in the atmosphere it is gradually decomposed, and a coating of insoluble silica is deposited on the surface of the stone, this coating protecting the stone from further atmospheric action, thereby preventing decay.

A safe rule to guide us in the selection of local stone for use in buildings in country districts, is to examine the quarry holes out of which these stones are usually taken. If we find the old exposed face of the rock showing no signs of decay, the pick marks being all distinctly seen on the face, we may safely use that stone for building purposes in the district local to the quarry. If, on the other hand, we find the rock face all mouldering and crumbling away, on no account should the stone be used for building purposes, as it will soon show the same signs in the building.

As an example of the use, with disastrous effects, of a local stone, I may instance the Wallace Monument, near Stirling. This monument was partly built of local stone, of which the binding material was of a clayey nature, and I understand that in some of the exposed parts it is decaying very badly.

It does not always follow that a stone which has shown good weathering qualities in the district in which it was quarried will possess the same good qualities in every district. We are all familiar with the history of Cleopatra's Needle, which stood in the Egyptian desert for over 2000 years, with every line on it as sharp and as fresh as on the day on which it was quarried. It was shipped to London, which, after an adventurous voyage, it reached safely, and was erected in a prominent position on the Embankment there. The London atmosphere had such a bad effect on it, that within two years it became so much decayed that a preservative had to be applied. We have had similar experiences, though perhaps not so prominently brought before us, in Glasgow. Stone that had been built for years in country districts without showing the slightest signs of decay, would not stand when built in Glasgow.

This brings us now to the consideration of the cause of this decay.

The theory that the decay is caused by the carbonic acid in the atmosphere has been put forward at different times by various persons, but a little examination will show that we have to look elsewhere for the cause. It is argued by the advocates of the carbonic acid theory, that the rain washing the carbonic acid out of the atmosphere deposits it on the surface of the stones, the acid soaks in. and acting upon the carbonate of lime decomposes it, thereby destroys the binding material, with the result that the stone decays. This works out very well as a laboratory experiment, a solution of carbon dioxide in water acting upon carbonate of lime as described, but when we come to apply it to stones in buildings the conditions under which this chemical action takes place are not quite so favourable for attaining that result. Carbonic acid gas being much less soluble in water than some of the other acids, all the rainfall that we have would be insufficient to dissolve or absorb enough carbon dioxide from the atmosphere to make a solution that would act to an extent sufficient to cause decomposition upon the carbonates. Further, if the carbonic acid be deposited on the stones, in the form of what might be termed a rainwashed solution, how is it that the surfaces of the stone which are most exposed to the rain, and which should be the first according to this theory, are the last to show signs of decay? We also see stones that are protected from the rainfall, in porches for instance, decaying very rapidly.

The carbonic acid in the atmosphere is practically the same in the country districts as in the cities and towns, as the following table will show :—

Over the open sea the proportion is	...	.032 per cent.
At Portsmouth ,, ,, ...	...	·032 ,,
,, Manchester ,, ,, ...	...	·037 ,,
,, Aldershot ,, ,, ...	...	·040 ,,
,, Tower of London ,, ,, ...	...	·042 ,,
,, Blackburn ,, ,, ...	...	·043 ,,
,, Chelsea ,, ,, ...	...	·047 ,,
,, Munich ,, ,, ...	...	·050 ,,
,, Arctic Regions ,, ,, ...	...	·055 ,,
,, Top of Mount Blanc ,, ...	...	·061 ,,
,, Chamounix ,, ,, ...	...	·063 ,,

By the courtesy of Mr. Harris, Chemist to the Glasgow Corporation, I have been supplied with the proportion found during recent tests in Glasgow, namely—0·46 per cent.

From these figures we see that the nearer to the sea the less is the quantity of carbonic acid in the atmosphere, and among the mountains, where green leaved vegetation is scarce, there is a greater quantity. For the purpose of comparing the effect of the atmosphere on stone, we may assume that the amount of carbonic acid in the atmosphere in the Callander district is very similar that in Glasgow, while the amount of rainfall is greater there than in Glasgow, or rather there are more wet days at Callander than at Glasgow. We find that Polmaise stone, when built on its natural bed, in the Callander district shows no signs of decay, while the same stone built in Glasgow, to judge from the experience of the Glasgow Municipal Buildings, decays very badly. From this, I think, we may infer that the carbonic acid in the atmosphere has little, if anything, to do with the decay of stones in buildings.

Although the proportion of carbonic acid in the atmosphere is virtually the same in cities as in country districts, the same cannot be said of the sulphur acids, which are chiefly the product of the combustion of coal, and are the chief cause of the decay of stones in cities. In the burning of every 100 tons of coal there is on an average one ton of sulphur emitted in the form of sulphur dioxide; sulphur dioxide as compared with carbon dioxide, being very soluble in water. When the sulphur dioxide comes in contact with aqueous matter or moisture and oxygen in the atmosphere a chemical change takes place, the result being that

the ton of sulphur produces three tons of sulphuric acid. The annual consumpt of coal per inhabitant in the United Kingdom is four tons, which gives the consumption in Glasgow as 3,100,000 tons. This would give 93,000 tons of sulphuric acid as being the quantity formed and deposited every year. This estimate, based on the average consumption in the United Kingdom, may be considered as being very much understated: seeing that Glasgow is a manufacturing centre, the quantity of coal annually consumed per head of the population will be greatly in excess of the average.

In an article on the atmosphere of Glasgow that appeared in the *Glasgow Herald* of 7th January, 1897, there is given a comparative statement of the proportion of sulphuric acid in the atmosphere of various towns. Taking Valentia, in Ireland, as the standard of purity, and giving the sulphuric acid in the atmosphere there as 100,

At Liverpool the quantity is	...	...	1,450
" Manchester " "	...	...	1,641
" Glasgow " "	...	...	2,571

If these figures are correct there is 25 times the amount of suphuric acid in the Glasgow atmosphere as compared with Valentia, nearly eighty per cent. more than in Liverpool, and fifty-eight per cent. more than in Manchester. This may be partly accounted for by the large number of manufactories and chemical works that are in our city. Although smoke consuming apparatus may be installed in greater numbers, thereby reducing the amount of solids floating about over the city, it would not reduce the amount of sulphur dioxide emitted while the coal is being burned.

Unlike carbon dioxide, as remarked above, sulphur dioxide is very soluble in water, so that on damp and wet days the sulphur dioxide in the atmosphere is converted into sulphuric acid. As has been already pointed out when the sulphur dioxide comes into contact with moisture in any form it is changed to sulphurous acid, which by oxidation is converted into sulphuric acid, so that every jet of steam which is playing into the air at the various works throughout the city is contributing to that chemical process, and on every drizzly, muggy day sulphuric acid is being formed and deposited in large quantities on our streets and buildings.

On a day of continuous heavy rain a certain amount of good is done by all the sulphurous and sulphuric acids which are

suspended in the air being taken up, the air washed pure, and all the sulphurous and sulphuric acids carried away by the heavy downfall of water.

On examining the records of the atmospheric conditions in Glasgow, out of 300 days it was found that 145 were dry and bright, when only a small percentage of sulphuric acid would be formed and deposited; 53 were days of continuous heavy rains, in which the air would be washed clean, and the acid carried away by the heavy downfall of rain; the remaining days were drizzly, constituting favourable conditions for the formation of the sulphurous and sulphuric acids, and in that form the product of the coal soaks into the streets, walls and roofs of the buildings in the city.

There is another point in connection with this part of the subject to which attention may be directed, and that is the amount, and the action of, dust in the atmosphere. The late Mr Aitken, of Falkirk, as the result of experiments, found that the particles of dust floating in the atmosphere act as a condensing surface for the aqueous vapour in the air, and that the more dust that is present in the atmosphere there is the more condensation. The acid in the air is thereby converted into a corrosive and destructive solution.

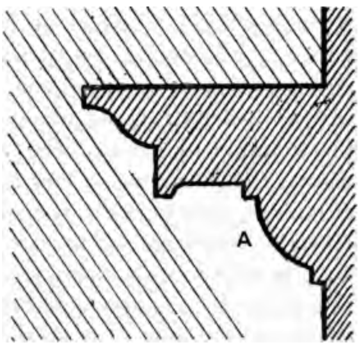
The effect of the gradual deposit of sulphuric acid on sandstone, in which there is a certain amount of lime, is that the stone absorbs the acid, and in so doing the lime is freed from the other constituent parts of the stone by the acid gradually working from the surface inwards, and disintegration sets in. This is first seen in the masonry immediately beneath the cornices and projecting courses, which is protected from the heavy rainfall that washes the exposed parts of the building, but these afford no protection on a damp day from the deposit of sulphuric acid, which soaks into every stone, and sooner or later the acid will honeycomb the surface of the masonry, and lead to general disintegration.

In stone, where carbonate of magnesia is found, the sulphuric acid acts upon the stone in the same manner as if the disintegration had been caused by frost.

The sulphuric acid deposited on the stone, may not be of sufficient strength to act at once upon the stone, but by subsequent evaporation of the water on a dry day the acid becomes sufficiently concentrated to dissolve the carbonates and cause disintegration.

Some time ago the writer made an experiment with a weak solution of sulphuric acid on some newly quarried stones (amongst others there was a piece from Polmaise quarry), and the acid had very little effect on any of the stones tested. At the same time a piece of Polmaise stone, which had been cut out of the Municipal Buildings, was immersed in a solution of the same strength, and after being a short time in the water it crumbled into sand. This proved that under ordinary conditions there is a continual absorption of the acid until a quantity sufficient to dissolve the binding material of the stone has been taken in, when the stone assumes a rotten appearance, and gradually crumbles away.

A practical proof that it is the sulphur acids that are responsible to a great extent for the decay of stones in buildings in this city was to be seen, until a few days ago, at the exit from the Central Low Level Station, on the west side of Hope Street. The masonry immediately above the doorway has all decayed, while there is very little decay of stone in the rest of the building. The staircase and doorway act as a ventilator to the station and tunnel, and travellers by the Central Railway do not require to be told of the amount of sulphurous acids that are there. The acid laden air ascending the staircase, and finding an exit by the doorway, strikes the stones immediately above the door with the effect described. This has now been covered by a verandah and cannot be seen.



The part of the building which generally succumbs first to the action of the acid is that underneath a cornice or projecting course, as shown at the part marked **A** on the accompanying diagram.

As already mentioned, on a damp day the acid is deposited on all parts of the building. On a day of heavy rain the exposed parts are washed by the rainfall, when a part or nearly all of the acid previously deposited will be washed off. No part of the rainfall reaches the protected parts underneath the cornice, the whole of the acid deposited remains there, soaking in and accumulating in strength with each fresh deposit,

until it is strong enough to do its deadly work of disintegrating and decomposing the stone.

Another theory of the cause of decay put forward is that which for want of a better name might be termed the bacteriological theory. The supporters of this theory say that the decay is caused by the action of a microbe which acts or feeds upon the carbonates and decomposes them. They may have some share in the work, but the question as to whether the effect of bacteria is large or small cannot be definitely decided until further research is made. The products of the decaying mass will show whether the bacteriological or the pure chemical effect is the larger of the two. I would welcome further investigation into this branch of the subject; but there is one argument put forward by the supporters of the germ or microbe theory which I would like to notice, that is that the decay often starts at the corner of a stone, and then gradually spreads over it instead of acting upon the whole simultaneously. We generally find that decay sets in first at the part most protected from the rainfall. There is, moreover, one point which must also be kept in view when discussing stone, and that is, that stone is not a homogenous material, such as a piece of steel, where all the different substances of which it is composed are distributed throughout in equal proportions. A stone may be more open or porous at one part than at another, or there may be a larger proportion of carbonates in some parts, and decay would commence first at these places.

Another cause of decay to which allusion may be made, and which is understood by all practical men, is the building of stones on "cant," or on edge instead of on their natural bed. The natural bed of a stone when exposed to the atmosphere by the stones being set on edge decays far more rapidly than the natural face of a stone. This may be seen in pillars at the ends of railings, such as in St. Vincent Street, where the stones are set on end. On examination of the four sides of the pillar we find that, in many cases, there are very few signs of decay on the two sides which form the natural face of the stone, while on the others, or bedsides of the stone, there is a large amount of decay. The County Buildings in Ingram Street are a good example of decay resulting from this cause. It does not require much reasoning to show how this cause of decay may be averted, namely, by seeing that all stones are built on their natural beds. I am glad to be able to say that there has been a great improve-

ment during the past thirty years in this respect, the introduction of sawing machinery having contributed in some degree to this, it being easier to saw a stone across the bed than with it, the reverse being the case when the stone had to be cut with wedges.

A further cause of decay which can be avoided is the redressing or cleaning of old stones. When this is done the air hardened surface that is on the stone is taken off, and the natural sap or moisture being dried out, there is no chance of a new protecting skin being formed. The result is that the stone succumbs in a very short time to the action of the acids in the atmosphere. In stones which had been exposed for over half-a-century, and had shown no signs of decay, on their being redressed decay set in immediately, and the surface of the stone became honeycombed in a very short time.

One writer in the recent correspondence in the *Glasgow Herald* advocated the seasoning of stones, but this, in my opinion, would be a step in the wrong direction. Stone cannot in this respect be compared with timber, as the natural moisture or sap has quite a different effect on the two materials.

Having shown what, in my opinion, are the chief causes of decay of stones in buildings, we have now to consider what stone has been found to be most suitable for use in Glasgow.

The theory has been put forward that the stone which contained the largest proportion of carbonates was the best that could be used. This theory was based on the assumption that the more carbonates the longer it would take the atmosphere to decompose them. At the first glance this theory seems quite a feasible one, but on further consideration we find that the larger the proportion of carbonates in stone the more of the carbonates will be exposed on the surface of the stone to the action of the atmosphere, and the disintegration of the stone will set in the sooner. In the stone having the smaller proportion of carbonates, the carbonates will be more finely distributed, and present a correspondingly smaller surface to the action of the acids in the atmosphere. Where there is a small percentage of carbonates, there is some other matter acting as the binding material, in most cases either oxide of iron or clay. If the binding material be of clay, then, as I have already pointed out, we may be sure that decay will set in. On the other hand if oxide of iron be the matrix or binding material, then the acids have little or no effect on it. It is here

that the chemist comes to our assistance by telling us of what the binding material of the stone is composed, and we are then able to form an opinion as to whether the stone is suitable for use in building operations or not.

The following figures are taken from a table of analyses of building stones prepared by the late Dr. Wallace, and submitted by him to a meeting of this section of the Philosophical Society twenty-two years ago, and show the percentages of carbonates found in twelve samples of stone that had been submitted to him.

Name of Quarry.	Amount of Carbonates.
Kenmure,	9·05
Overwood,	4·27
Giffnock,	2·17
Dunmore,	3·60
Ravenscraig,	·52
Craigleith,	·37
Polmaise (white),	12·58
Inverkip,	1·46
Bothwell Park,	·84
Corsehill,	1·03
Wemyss Bay,	1·11

There appears to be a variation in the proportion of carbonates, etc., in some of the stones mentioned in the above list; for in another table of analyses, prepared by a Mr Wallace Young, the amount of carbonates in Giffnock stone is given at 10·02 per cent., and an analysis, which was made at my request by Dr Henderson, Professor of Chemistry, Technical College, Glasgow, about six months ago, there was found to be 6·5 per cent. of carbonates in Giffnock stone.

In an analysis of red stone from Closeburn quarry, Dumfriesshire, with which I have been supplied, the amount of carbonates is ·63 per cent., and the amount of oxide of iron 1·04 per cent. In a piece of Locharbriggs stones, which was analysed for me by Mr. Harris, Chemist to the Glasgow Corporation, the amount of carbonates was ·53 per cent., and of oxide of iron 1·28 per cent. I had an opportunity recently of discussing this subject with a chemist of high standing in his profession, and the opinion that he expressed on the subject of decay in stone may be briefly summarised as follows:—"The broad fact is that the stone which has the largest proportion of carbonates in its composition—provided that other things, such as porosity, are equal —will be the first to show signs of decay."—This, I think, is

borne out by our experience of the various building stones used in Glasgow.

The stone, on our list, which shows the largest amount of carbonates is Polmaise, and the experience of the use of that stone in the Glasgow Municipal Buildings has been a sorry one. Comparing it with Dunmore stone, which, in these buildings, has not decayed to any such extent as the Polmaise stone, we find that in the Dunmore stone there are 3·60 per cent. of carbonates as against the 12·58 in Polmaise, nearly four times as much.

If we look at Craigleith, which may be termed the ideal stone for weathering, although it was not that from the masons' point of view, we find the total amount of carbonates to be only ·37 per cent., which further bears out the theory that the stone with the smallest amount of carbonates is the stone that shows the least signs of decay.

In the red sandstone, as a general rule, there is a far smaller proportion of carbonates than in the white. There are exceptions to this, however. In the old red sandstone of Finnich Glen, for example, the proportion of carbonate of lime is very high, ranging from 11 to 16 per cent, but it is a stone which wastes away in its natural position, therefore it may be classed as one of the stones that should not be used for building purposes.

The red stones, chiefly used for building purposes in Glasgow, are from the Dumfriesshire quarries. From the analyses already given, it will be seen that the proportion of carbonates in them is very small, while the proportion of alkalies, which go to the formation of the hard skin already mentioned, is large, being nearly 2 per cent., and to these qualities, I think, we may attribute the success of the red stones as compared with the white, in resisting the attacks of the Glasgow atmosphere.

If we examine any of the Buildings which have been erected in Glasgow with stone from that part of Dumfriesshire which lies between Thornhill on the north and Dumfries on the south, and includes Gatelowbridge, Closeburn, Corncockle and Locharbriggs quarries, we find very little, if any, signs of decay. Take for instance the warehouse in Sauchiehall Street, which was erected by Messrs Cumming & Smith twelve years ago, all the stone used in that building was from Locharbriggs. Compare that with the National Bank Buildings, Buchanan Street, erected four years ago with stone from Plean and Giffnock quarries, and on which there is already a considerable amount of decay, and I think you will

agree that the red stone stands, or to use a common expression, wears best in Glasgow.

There are other quarries in Dumfriesshire further south than those mentioned, in the stone of which, to judge by appearance, there is a larger proportion of clay, thereby making it, in my opinion, not so suitable for use in Glasgow.

On some of the older buildings in Glasgow the signs of decay are not so marked as in some of the newer buildings, and the question has been asked—how can this be explained?

At the time that these buildings were erected the city of Glasgow covered a very small area compared with what it does now, and the sulphur acids, which were produced at that time chiefly from domestic fires, would be very quickly diffused among the purer air of the surrounding country districts, and they would become so finely distributed that they would have very little, if any, effect on the buildings. The hard skin which forms, in most cases, on stones exposed to the atmosphere, would have time to get fixed before it was attacked by the sulphur laden atmosphere of the present time.

The stone with which the houses in Richmond Street and George Street, for instance, are built, was quarried from local quarries. I understand that there was a quarry near where Queen Street Station now is. While excavating the site of the new Technical College buildings we removed a considerable quantity of freestone, and at George Street front there was a part which had the appearance of having been quarried at some time previous to the formation of George Street. A piece of this stone was analysed in the Technical College Laboratory, and the proportion of carbonates it contained was only 2.04 per cent. This may partly explain why the stones in these buildings have withstood the attacks of the Glasgow atmosphere so much better than the stones in some of the modern buildings which are built of stones containing a larger proportion of carbonates.

As a general rule the white stone carries a greater load before crushing than the red. It is therefore more suitable to use for heavy buildings, and as some of the red also shows signs of decay the question of prevention has to be faced, and we have to consider how this can best be effected.

A simple remedy has been suggested, namely, to give the buildings a periodical wash down, thereby washing off any of the acid laden dust that might be lying about underneath and on pro-

jections. This, however, is not a success as a preventative of decay to judge by the experience of the Savings Bank buildings at the corner of Ingram Street and Glassford Street. That building has been washed down regularly, yet some of the stones are showing signs of decay.

The first signs of decay, as has been already mentioned, are to be seen underneath projections, such as cornices, copings, etc. The theory has been put forward that this was caused by the acid laden water falling upon the top or exposed surface, and at once passing from the upper surface, which is the first to dry, and hanging on to the lower surface indefinitely, where it can dissolve the carbonate of lime at its leisure. The remedy suggested is to put a waterproof coat on the top.

The cornices of the Municipal Buildings and the Sanitary Chambers were, I understand, protected by a waterproof coat on the top, yet this has not prevented these cornices from decaying, and the course immediately underneath them from decaying also. There are also plenty of instances in Glasgow, such as in Belhaven Terrace, where the cornices are covered on top with lead, and yet are a mass of decay underneath.

This suggested remedy was bound to fail, for a very little consideration would show that it would be a very long continued rain which, falling upon a weathered or sloping surface, would soak through a heavy cornice such as that of the Municipal Buildings. The theoretical basis of the remedy is thus shown to be erroneous.

For an effective preservative we have to proceed in the direction of assisting the stone, by forming on the surface of the stone an insoluble silicate, or in other words a skin, which will withstand and be impenetrable to any of the acids that are floating around in our atmosphere.

One remedy of this nature is the coating of the stonework with paraffin oil, in which a small quantity of paraffin wax has been dissolved. The difficulty with this preparation is the getting of it to dry properly, as the building must be perfectly dry before the stone will absorb it.

To form an insoluble silicate on the surface of the stone, a solution of silicate of potassium is taken and applied with a brush. Silicate of sodium, produces the same effect, but is said to give rise to, after a time, an unsightly efflorescence. A chemical action then takes place, the alkaline silicate being gradually decomposed

by the action of the carbonic acid in the atmosphere, and a coating of insoluble silica is deposited on the stone, protecting it from further atmospheric action. This process has been very successful in Paris and several other French towns.

In our moist climate, however, the application of a silicate in this manner is attended with more uncertain results, the liquid coating being liable to be removed from the surface of the stone by rain, or even by the ordinary humidity in the air, before it has time to absorb sufficient carbonic acid to precipitate the silica in an insoluble form.

Several expedients have been adopted, or suggested, to overcome this difficulty, and solutions have been prepared, and are sold under various names, such as stone liquid, and so on. One of the best known and most used is Czeremley's Stone Liquid.

This preparation has been applied successfully in a great many instances, and where it has failed to act the preparation may not have been to blame, but rather the conditions under which it has been applied.

As can be readily understood, there is a large quantity of moisture in a newly built wall, which gradually dries out by evaporation in the summer time, and in the winter time by the action of frost. All the moisture is, in due time, drawn to the exposed surface, so that at least one summer and one winter should be allowed to pass before any preparation, of the nature of a preservative is applied. In the case of important buildings, where the walls are heavy and thick, two years at least should elapse to allow the moisture to thoroughly evaporate. Any water sealed up in the stone by the coating would be acted upon by the next winter's frost, and would result in a peeling off of the hardened skin, leaving the stone in a worse condition than if it had never been treated with a preservative.

This applies also to the time of the year in which the work should be done. In my opinion, unless in the midst of what might be termed exceptional weather conditions, preservatives of this nature should only be applied during the period of the year commencing in the beginning of May and ending at the end of August. The application of a preservative, under unfavourable conditions, may explain, in some cases, the reason of its failure. Stones may be cut out and renewed during the remainder of the year, but it is only during the period mentioned that weather conditions suitable for the application of a preservative of stone can be found.

Another cause of failure on the part of a preservative may be explained by the insertion in a building of a newly quarried stone in place of a decayed one, and the application of the preparation before the natural sap has dried out, with the result that the hardened skin peels off, and the blame is laid on the preservative and not on the true cause, namely—the moist condition of the stone.

I will now bring my paper to a conclusion by expressing the hope that the reading of it may be of some little benefit and assistance towards the finding of a practical solution of the cause and prevention of decay of stone in buildings. It is only by attacking the problem from every side that we can hope for ultimate success. In the present state of our knowledge we cannot afford to discard any detail as too insignificant for consideration, nor can we dispense with any assistance that may be made available. We may rest assured that, if results are properly co-ordinated, the very important and urgent problem we have been discussing will at length yield up its solution to the combined efforts of theory and practice as represented by the chemist, the bacteriologist and the practical man.

On the function of the Water Vascular System in Rotifera, with Notes on some South African Floscularia. By WILLIAM MILNE, M.A., B.Sc.

[Read before the Society, 30th November, 1904.]

THE smallness of the parts of the water vascular system and the optical difficulties arising from their position in the body have caused a great diversity of views regarding structure and functions.

The structure is so little known that most of the inferences as to function are supported from analogy. The different views held as to function are, that it is

(1) Respiratory.

(2) Renal.

(3) Partly Respiratory and partly Renal.

Hudson and Gosse were quite at variance in this matter.

Some time ago I came across a Floscule at Uitenhage, to be afterwards described as F. Moselii, in which the vascular system is represented by an extraordinary development, quite different from anything I have seen in any other rotifer.

In this Floscule, in the region of the ovary right and left, are two organs, pyriform in outline from above, but more flattened or compressed from the side view which shows a cleft or depression in the front shoulder. These organs have a brownish yellow colour—in some the brown is darker than in others—and are very finely granular in structure. The organs are of definite shape and structure, surrounded by a membranous investment and not accidental aggregations of granular floccose material, for those in one specimen are like those in all others in shape, relative size, position and practically in colour.

From the posterior end of each a finely granulated tube or cord proceeds to a clear vesicle adjoining and in communication with the cloaca. This vesicle though capable of contraction, has no regular period of contraction, and I have only once observed it discharging.

The pyriform glands lie free in the body cavity and are held loosely in position by fine muscle attachment to the sides of the Floscule. These muscles proceed from the front of the glands from where also from each there extends forward a connecting tissue band of small dimensions and which could not be traced far. From this there is a muscle of extreme tenuity branching over towards the other side in the neighbourhood of the junction of the stomach and crop.

I think then that views (1) and (3) are hardly tenable, and that there can be little doubt that these organs just described are kidneys communicating through a duct with a bladder which discharges directly into the cloaca.

What connection then has this arrangement with the vascular system found in other rotifera?

Dr Hudson states that the tubes (lateral) appear to be surrounded with a granular floccose material which here and there dilates into irregular masses. These tubes often loop or form plexuses about the neighbourhood of the ovary. In a Limnias I found at Uitenhage there was regularly a thick coating of granular matter around the canal, where the plexuses are usually found, forming an elongated swollen mass, but not definite in shape.

Suppose this aggregation of granules to increase till it incloses all the loops and forward part of the lateral tube vibratile tags and all, and to assume a definite shape with an investing membrane, and we have an organ similar to the one I have just described as found in Fl. Moselii.

Dr Hudson seemed to be on the right lines when he asked the question, Is the substance surrounding the lateral canals a glandular secreting substance? As I take it these granular particles in the kidneys are the secreting agents purifying the perivisceral fluid, and that the incorporated plexus of lateral tubes and vibratile tags drain off this secretion to the bladder from which it is discharged through the cloaca.

These granules are very common in Floscularia as noted by Dr Dobie, but he considered they were connected with the nutrition of the animal, while my contention is that they are secretory agents purifying the surrounding blood-fluid.

The only remnant of the vascular system as seen ordinarily in rotifera—in addition to what I have described—consisted of two feeble vibratile tags, rather imperfectly seen, near one of the eye spots and probably functionless.

Floscularia Moselii, Sp. nov., (Plate I., Figs. 1-6) Lobes five; dorsal lobe largest, two large ventral lobes—about three-fourths of dorsal—two small lateral lobes.

Some time ago when studying species of Limnias, specimens of Floscularia frequently occurred in the water. Glancing casually at these with a low power, there seemed a considerable variation in examples that looked to be one species. On examining more carefully, however, I found that there were three species F. Campanulata, F. Ambigua, and the one I have named above F. Moselii, and that the last had characteristics so pronounced that afterwards, even with the one objective, I could tell whether the example under review was F. Moselii or not. The presence of the great—for a Floscule—dorsal antenna and the large yellow-brown kidneys told at once that the species was F. Moselii. But should an egg be noticed lying alongside, there was no need to look further, as the species is viviparous and never deposits eggs. I do not refer to the winter eggs. I only once saw one of these, very dark, and having the usual appearance. I am under the impression that this egg was present with developing embryos of summer eggs, but have no record in my notes.

The three large lobes arch inwards slightly, and are similar in shape. The width of each is fairly uniform upwards from near the base to near the top, where it is rounded off. The inner surface of each is slightly concave. The two lateral lobes are very small, but distinct. The lobes and interlobular spaces bear setæ.

The dorsal antenna is easily seen when the corona is closed, projecting forward, and is slightiy mobile at the base. The two dorso-lateral antennæ are quite evident, though small. There is no difficulty in making out the cilia in the vestibule and the Œsophageal membrane, as the animal is very transparent.

The jaws (Pl. I., Fig. 3) lie posterior to the crop and have each two teeth. In the embryo, the two teeth are seen to be of unequal length.

Each pair stabs sharply through the other downwards, and then tears backwards through the food. The unci are rods with bulbed outer ends, incipient manubria, and dividing into two teeth at the inner ends. The manubria seem to be attached to great muscular parts which narrow and then expand into muscular bulbs near the fulcrum, but this is very difficult to make out, and the whole might be the sectional appearance of a mastax.

Each ramus consists of two loops set oppositely. The upper loop is attached to the malleus, and hinged to the second loop, which in turn is hinged to the fulcrum. When the teeth move forward bearing on the upper loop, the pressure is transmitted to the hinge, and the upper loop swings inwards on the hinge, with extreme rapidity, till it lies inside, and almost parallel to the second loop. A certain amount of lateral play at the top of the second loop, is permitted according to the amount of pressure transmitted to the second hinge. When the teeth have been driven forward with great force, the rebound at the two hinges helps to throw the teeth back into their normal position.

The stomach and intestine are of the ordinary form; the rectum opens through the cloaca, and is short, and not bent upwards when extruded.

There are two large elongated club-like gastric glands extending from opposite the posterior of the vestibule backwards over the crop, and joined by long ducts deep into the shoulders of the stomach. They are greyish in appearance, and are nucleated. When the Floscule is viewed laterally the glands and stalks can be very clearly defined, lying more to the dorsal than ventral surface. The other prominent glands are the kidneys, already described, lying free in, and bathed by the perivisceral fluid and held in position by muscle attachment to the inner dermis. The ducts connect with the bladder, which discharges through the cloaca. The kidneys stand out most prominently, as they are usually seen over an embryo.

The ovary extends forward well up to the crop, and is of large size. It communicates directly with the cloaca through an oviduct.

Two or three embryos are usually seen in the ovary in different stages of development. (Pl. I., Fig. 4) shows one in advanced stage. Anteriorly an invagination has taken place and has given rise to cornua, vestibule and œsophagus. There are frontal cilia, and the inner layer of cells of hypoblast is forming the coronal setæ.

In the adult, when the corona is closed, the setæ are tucked away in a manner which recalls this appearance in the embryo.

It is difficult to make out how the rest of the alimentary tract arises. The jaws and intestine develope fully before the crop and stomach. The outline of the stomach is indistinct at this stage, as the contents are similar to wall structure, and somewhat viscous as if the cells were undergoing degeneration. This appearance is still maintained in the early stage of the young.

A thickening or unequal development of the cells along the posterior half of the ventral surface gives rise to the foot, and a hollow along the interior of the foot, forming a continuation of the body cavity can be seen. A circlet of cilia is developed at the end of the foot. (Pl. I., Figs. 5, 6) show two stages in the young. The first is sitting down over the foot. In the intestine there are a few brown concretions, probably waste cell matter, and not renal as Leydig supposed in similar cases. The stomach walls are indistinct as already stated. The pre-oral cilia are active, and the vestibule cilia are plainly visible. The dorsal lobe is considerably developed with longish setæ. The two ventral lobes are partly formed, but are still fleshy masses. The setæ are developed, but though a few point outwards several point inwards (Fig. 6) showing that the lobes are not yet capable of being everted. Each lobe has still superfluous cell matter under it to work into itself and complete the lobe. In (Fig. 6) the dorsal lobe has two fleshy parts from which the two small lateral are apparently to be evolved.

The foot of the adult when fully stretched is somewhat longer than the rest of the body. It has a ringed appearance resembling a cork screw.

The great transparency of the corona and vestibule allows of a very fair view of the muscles, and the following seems to me the arrangement whereby the opening and closing of the entrances to the vestibule and crop are controlled. There are fine muscles giving an oval outline to the entrance to the vestibule. The action seems to start close to the nervous ganglion (*n*) (Pl. I., Fig. 2) with muscle at (*e*) which shoots forward, bringing (*d*) backward and upward. The circular muscles at the vestibule entrance close the opening, (*a*) is drawn across and upward accompanied or accentuated by (*g*) which the slightest motion of the ventral lobe acts on. The motion of (*a*) acts on (*b*) and (*b*) on (*c*) pulling upwards, and fine muscles from (*b*) and (*c*) to crop lining, close to crop aperture, pull the lining up opening the entrance to œsophagus, and giving the appearance of the two lips spoken of by other observers. All this may take place without being followed by the swallowing or gulping action. The lips at the crop entrance may often be seen rising in a tentative sort of way and retiring again. To lead to the gulping, further action takes place. Attached to (*h*) and (*l*) are muscles proceeding to a knob on the top of the dorsal lobe, and probably similar ones from (*g*)

to the ventral lobe. These lobes are often seen closing slightly, and gently accentuating through these muscles the action already described, but something more is required before the contents of the vestibule are thrown into the crop. This is a squeezing action by circular muscles, not made out, between the corona and vestibule (probably where the great muscles from the foot are attached.) This sudden firm squeeze, seen accompanying every gulping act, causes great pressure on the vestibule downwards towards the opened crop entrance, which receives the rush of vestibule contents and relieves the pressure.

The muscles (*a*) (*b*) (*c*) and (*e*) seem more firm and chitinous than the ordinary muscles, and have an appearance more like the jaws.

The nervous ganglion lies dorsally between the two lateral antennæ and straight behind the dorsal one. It seems to have nerve threads connecting with all the antennæ.

The eyes are rather dull red, and are seated on muscle or nerve threads which apparently join to the ganglion.

Length $\frac{1}{30}$ inch.

Common.

It has been suggested to me that this species is the same as F. Trilobata, not from any likeness to Dr Hudson's figures, but to a sketch by Dr Collins the discoverer of the species. The sketch is from the same point of view as the one I give. A large dorsal antenna is shown, and the general outline is somewhat similar, but if the proportions be examined it is found that the gap between the ventral lobe and the dorsal, is to the ventral lobe almost as 3 : 1 in F. Moselii, and as 1 : 1 in F. trilobata.

Again were this F. trilobata, then Collins and Hudson both failed to see the lateral lobes, and yet Dr Hudson saw clearly an outer and inner row of setæ running past the lobes, much more difficult to see than the lobes themselves.

No mention is made by either observer of the organs I have called kidneys and which are so prominent.

Now, Dr Hudson was so careful and accurate in his observations that I do not think it possible he could have missed all these points which are so easily seen.

F. Annulata, Hood. *F. Unilobata*, Wierzejski. (Pl. II. Figs. 1-4.) Lobes three. Short setæ on lobes and all round margin, except on the vertical sides of the dorsal lobe.

There are two or three positions of this Floscule which give the appearance of one lobe only—the dorsal.

This lobe is slab-like, and moves up and down as if on a hinge. The bands round the neck, mentioned by Hood, are very prominent.

The body is very dense owing to the number of granules which stream along slowly, but have no individual motions. The corona and vestibule also contain a large number of these granules. It is a sturdy animal and not easily disturbed when feeding, and the stomach is generally packed with food.

The foot is rather shorter than the rest of the body, and is lumpy and extends in a sluggish way after the manner that contractions travel up and down earths worms.

But perhaps the most characteristic action is, when it expands the corona. A squeezing action begins from the crop and proceeds slowly, and with increasing force forward propelling the fluid in advance, and driving out slowly the lobes and folds of corona, till the whole anterior part looks like a bouquet (Pl. II., Fig. 4.) The constricted part reminds one of the appearance a wet blanket has when rung tightly between two persons, or of a tight fibrous bundle, so powerful is the muscular constriction. When the corona is half unfolded the fluid flows in again and the neck blows out slowly, and the wrinkles disappear, as it regains its bull necked appearance seen laterally, at the same time the lobes lift slowly up, the dorsal one last.

Wierzejski's figure of Unilobata is very like (Pl. II., Fig. 1), and still more like a sketch I have of a F. annulata which has not quite reached the adult stage. The short stumpy nature of the foot agrees so that I conclude that F. unilobata and F. annulata are the same species.

Length $\frac{1}{33}$ inch.

Not rare.

Floscularia sessilis, sp. nov. (Pl. II., Fig. 6.) Knobs five—without stalks. Setæ only on knobs.

This is a small Floscule. The five knobs are practically seated in the margin of the corona, and bear each eight or nine short

setæ (not equal to width of neck), giving a star-like appearance to each knob. The corona is small and not wider than the body. There is a rib-like thickening of the dermis from the knobs backward. I could see no tube and there seems to be none, as the Floscule when feeding sways from side to side for more than a quarter-circle.

There is a deep narrow vestibule and the vibratile cilia show distinctly. Two tags were seen near each other in the neck just above the ganglion.

The stomach extends well forward, and is generally packed full of diatoms.

The foot is of about the same length as the body, and has at its extremity a very short peduncle.

Length $\frac{1}{100}$ inch.

Rare.

Floscularia minuta, sp. nov. (Pl. II., Fig. 5.) Lobes three—setæ only on the dorsal lobe from which also project two membranous bands.

This is the smallest Floscule, and is liable to be overlooked, not only on account of its small size, but from the nature of its habitat, which might be described as a thicket of rubbish.

At first I thought the corona was lobeless, but a closer examination showed three lobes, but rising very slightly above the rest of the corona. The dorsal lobe seems to have a very slight depression in it, and might almost be called double. But this might be an appearance due to the way the corona is closed. It folds in, in two halves, the lateral lobes being the middle of each half, and the dorsal lobe folded in two. The outline of the corona is oval. The setæ are few and short, and situated only on the dorsal lobe, on which are the two peculiar membranous bands, outgrowths of the lobe.

The rim of the corona is thickened all round, more especially in the lateral lobes.

There are two lateral antennæ with setæ.

The egg is of very large size, its length being about one-fourth that of the whole body.

The foot is of the swollen type about one-half longer than the body, ending in a fine point, but apparently having no peduncle. There are numerous granules ever in motion and sometimes streaming along.

Length $\frac{1}{200}$ inch.
Rare.

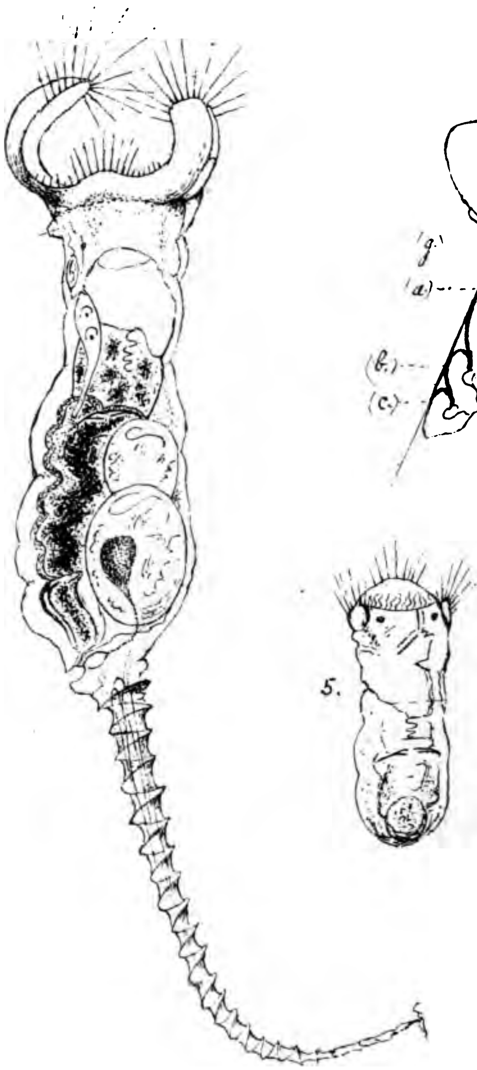
F. regalis, Hudson. *F. proboscidea*, Ehrenberg. Lobes seven, knobbed. Setæ on knobs and all round the margin of corona.

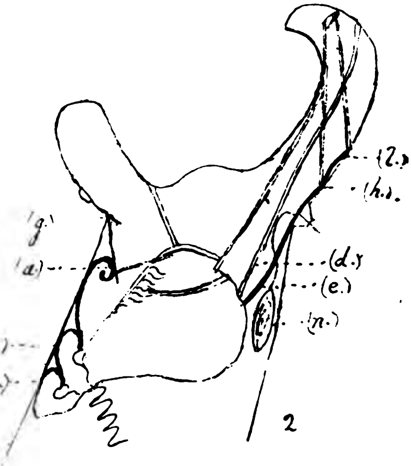
The marginal setæ are finer and not so easily seen as in most other species, so that it is possible they may have been overlooked by Hudson and Ehrenberg. This would have to be settled by future observations on the English F. regalis. Meanwhile, I assume that the South African species described above is the same as F. regalis. One very noticeable part of it is a peculiar chain of large round cells or cell masses, just under the coronal margin, with fine muscular or nerve attachment downwards. There are one under each lobe and one between and all in contact.

Hudson agrees with Grenacher that F. campanulata and F. proboscidea are the same. I do not see how they could possibly be the same. But were F. regalis substituted for F. campanulata in the following suggestion of Grenacher's, "that the snout-like organ of F. proboscidea is only the dorsal lobe of F. campanulata seen before the corona is fully expanded," then we have I think Ehrenberg's F. proboscidea.

When I first saw this Floscule I thought it was a six-lobed species, as the dorsal lobe was not protruded. Afterwards the dorsal lobe was seen projecting inwards horizontally at or just under the level of the margin, and the anterior end bent upward elbow-wise—an appearance which might easily suggest a proboscis if imperfectly seen. The Floscule often retains this position for a considerable time. Accordingly I have little doubt but that F. proboscidea and F. regalis are the same.

PLATE I.





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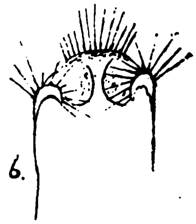
5.



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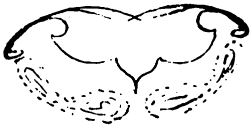
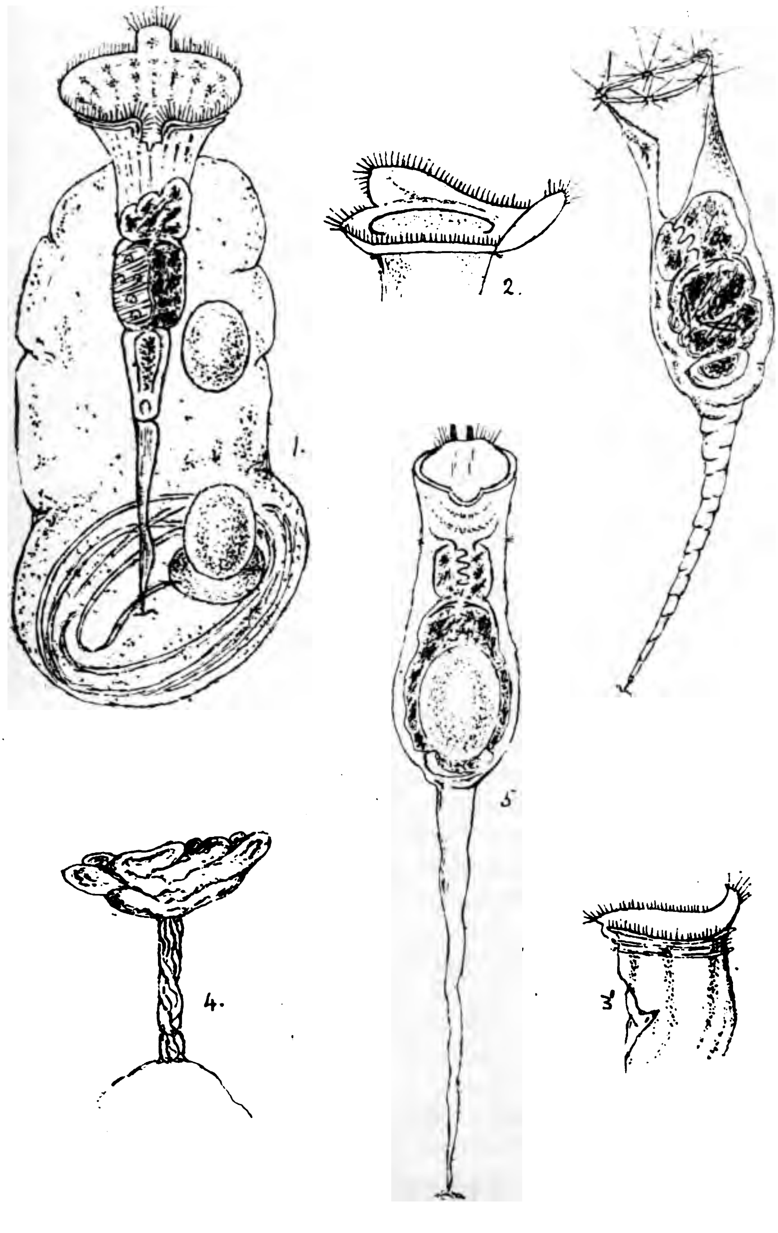


3.

PLATE II.



EXPLANATION OF PLATES.

PLATE I.

Fig. 1. F. Moselii, side view.

Fig. 2. " " showing muscles controlling the opening and closing of vestibule and crop entrances.

Fig. 3. Jaws of F. Moselii.

Fig. 4. Embryo of F. Moselii.

Figs. 5, 6. Early stages of the young of F. Moselii.

PLATE II.

Fig. 1. F. annulata, ventral view.

Fig. 2. " " dorso-lateral view from slightly above.

Fig. 3. F. annulata, lateral view.

Fig. 4. Half opened corona of F. annulata.

Fig. 5. F. minuta.

Fig. 6. F. sessilis.

Experimental Work at Low Temperatures.

By H. Stanley Allen, M.A., B.Sc.

[Read before the Society, March 22nd, 1905].

1. Methods employed in the liquefaction of gases.
2. The low temperature plant at the Blythswood Laboratory. Liquid air apparatus. Liquid hydrogen apparatus.
3. Demonstration of the properties of liquid air.
4. Applications of liquid air in scientific research. Dewar's method of producing high vacua by the absorptive power of charcoal at low temperatures. Results obtained at Blythswood in exhausting X-ray bulbs.

1. Methods Employed in the Liquefaction of Gases.

The great advances made in the attainment of low temperatures within the last ten years have been the result of long and patient work on the part of many investigators. Ten years ago liquid air could only be obtained at a few cryogenic laboratories: hydrogen had not yet been obtained as a static liquid. Now the subject may be said to be entering on the second stage of its history, when apparatus for the production of liquefied gases has become an essential feature in the equipment of a chemical or physical laboratory. It is now possible to obtain well designed apparatus for the production of liquid air or of liquid hydrogen in quantity. It is the object of the present paper to give an account of such a plant, and to refer to some of the uses to which these frigid liquids can be put in scientific investigation.

It is unnecessary to consider at length the history of the liquefaction of gases, but I may recall some important points.

For each substance there exists a critical temperature and a critical pressure. If the temperature exceed the critical temperature, or if the pressure be less than the critical pressure it is impossible to liquefy the gas. A "vapour" may be defined as a gaseous substance at a temperature lower than the critical temperature.

Two methods may be employed, either singly or in combina-

tion, to bring about the liquefaction of a gas—increase of pressure and diminution of temperature. Increase of pressure alone will not effect the liquefaction if the temperature be too high, neither will diminution of temperature alone be successful if the pressure be too low. These facts, resulting from the classic experiments of Dr Andrews on carbonic acid gas, explain the failure of the earlier investigators to liquefy the so-called "permanent" gases by the application of pressure. In one experiment Natterer employed the enormous pressure of 2,790 atmospheres in an attempt to liquefy air—without success.

Davy and Faraday were successful in liquefying most of the commoner gases with the exception of those which were regarded as "permanent." The gas was generated in a sealed tube one limb of which was cooled by a freezing mixture.

Thilorier in 1834-5 produced liquid carbonic acid in quantity, and by the rapid evaporation of a jet of the liquid he obtained the solid. It was not until 1877 that Pictet and Cailletet simultaneously announced the liquefaction of oxygen. The methods employed by these experimenters were entirely different, but both have proved of the greatest importance in the production of large quantities of liquid air. Pictet made use of the cooling effect of a liquid evaporating under diminished pressure. Cailletet compressed the gas to 400 atmospheres and then allowed it to expand suddenly. The cold produced was sufficient to partially liquefy the gas. It must be pointed out that the rarefaction of a mass of gas is not in itself sufficient to lower the mean temperature. "Where no work is performed there is no absolute refrigeration." But if the gas in expanding does external work, either in moving a piston or in forcing the gas in front of it through an aperture, it must become cooled.

There is yet another method which may be employed in the liquefaction of gases. Cooling may be the result of work done against *internal* stresses. In 1848, Joule and Lord Kelvin showed that with most gases a fall of temperature takes place when the gas is allowed to expand freely. With hydrogen at ordinary temperatures the converse is the case—the temperature rises on free expansion. Hampson and Linde have independently made use of the Joule-Thomson effect to bring about the liquefaction of air.

The problem of the liquefaction of hydrogen was attacked by Wroblewski and Olszewski, but though they described the produc-

tion of a mist or spray of hydrogen they did not succeed in obtaining the liquid in static form. This was first accomplished by Dewar in 1898. Subsequently the liquefaction of hydrogen was studied both from a theoretical and a practical point of view by Travers. The method employed in his apparatus is identical in principle with that used by Hampson and Linde, but it is necessary that the hydrogen should undergo a preliminary cooling to render the Joule-Thomson effect available.

2. The Low Temperature Plant at the Blythswood Laboratory.

The plant for low temperature research recently set up at the Blythswood Laboratory comprises apparatus for the production of liquid air and also liquid hydrogen. The installation for liquid air (March, 1904,) consists of a Whitehead Torpedo Compressor working in conjunction with a Hampson Liquefier. The air of the laboratory freed from carbonic acid by passing over trays of slaked lime in the "low pressure purifier," is compressed in two stages to nearly 200 atmospheres (3,000 lbs. per square inch). The cylinders of the pump are kept cool by water circulating through surrounding tanks. From the compressor the air passes to a strong cylinder in which the bulk of the water is deposited, then through a second cylinder containing solid caustic potash. The pure dry air enters the Hampson liquefier, and after passing through four coaxial spiral coils of copper is allowed to expand at a throttle-valve. The air cooled by expansion passes back over the coils and so cools down the incoming air. In this way a continually increasing effect is produced, and the temperature is reduced to such an extent that liquefaction at length occurs. This generally takes place in seventeen or eighteen minutes after starting the compressor. The liquid air is collected in a chamber containing 127 c.c. from which it is drawn off at intervals of 5 minutes. The present apparatus is capable of producing a litre and a half (nearly three pints) in an hour. The compressor requires six horse-power to drive it, and one man requires to be in constant attendance.

The liquid hydrogen plant was set up under the direction of Dr Morris Travers. It consists of apparatus for the production and purification of hydrogen gas and a liquefier constructed by Brin's Oxygen Company to Dr Travers' designs. The hydrogen is generated in a lead vessel by the action of dilute sulphuric acid

on pure zinc. The gas is purified by passing it through four stoneware jars containing pumice-stone moistened with the necessary reagents. The first jar contains potassium permanganate, the second and third silver sulphate suspended in water, and the fourth caustic potash. The gas is stored over water in a gasometer holding 100 cubic feet (3 cubic metres).

The production of liquid hydrogen presents more difficulties than the production of liquid air. The nearer we approach the "absolute zero" of temperature, the more difficult does further progress become. The experiments of Joule and Thomson showed that in the case of hydrogen, the gas, when allowed to expand freely at ordinary temperatures, was heated instead of cooled. It is only when the initial temperature is below $-79°$ C. that the converse effect is produced. It therefore becomes necessary to cool the gas below this temperature before it enters the "regenerator coil" of the liquefaction apparatus. After the compressed gas has been dried it enters the liquefier in which it passes through a single coil of copper pipe. One portion of the coil is cooled by liquid air, and in the succeeding portion the temperature of the gas is still further reduced by liquid air evaporating under diminished pressure.

The "regenerator coil" which is cooled by the current of hydrogen after expansion at the valve, is contained in a chamber 80 mm. in diameter and 190 mm. long. In this apparatus there is a second regenerator coil over which the cold hydrogen passes, with the result that the gas leaving the liquefier is only a few degrees colder than the gas which enters it.[1]

This plant was first used on January 14th, 1905, under the superintendence of the designer, and liquid hydrogen was made on that date for the first time in Scotland. About 400 c.c. of the liquid were collected in a Dewar's flask provided with a double vacuum jacket.

3. Demonstration of the Properties of Liquid Air.

[A number of experiments were shown to illustrate the most striking properties of liquid air. The low temperature attainable by its use was shown by freezing water, mercury, alcohol, and

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[1] A full account of the apparatus constructed by Dr Travers for the liquefaction of hydrogen may be found in vol. 44 of the Smithsonian Miscellaneous Collections. The apparatus is also described in his book "The Experimental Study of Gases." 1901.

ether. The effect produced on certain solids was demonstrated. The power of the liquid to support combustion owing to the evaporation of nitrogen was illustrated, and finally it was shown that liquid air could be employed as a motive power by using it to drive a small engine.]

4. APPLICATIONS OF LIQUID AIR IN SCIENTIFIC RESEARCH.

The introduction of liquid air and liquid hydrogen as reagents in the laboratory has opened up a new field for scientific investi gation. The study of the properties of matter at low temperatures is now being carried out by many experimenters in various directions. Alterations in molecular structure, or in chemical activity, or the altered relations of matter in regard to heat, light, electricity and magnetism, are all in need of further elucidation.[1]

One of the most important applications of liquid air is its use as an analytic agent in separating the various constituents from a gaseous mixture. In liquid hydrogen an even more powerful reagent is available. It was to effect the separation of the gas neon from helium and argon that Dr Travers constructed his first liquid hydrogen apparatus (1900).

[The use of liquid air as an analytic agent may be illustrated by a simple experiment. A stream of coal gas is passed through a glass tube in the form of a spiral, and ignited at the open end. If the spiral is immersed in liquid air the less volatile constituents are liquefied, and the gas remaining (consisting of carbonic oxide and hydrogen) burns with a non-luminous flame. (Dewar, Proceedings of the Royal Institution, No 94, p. 478). After the gas has passed through the tube for some minutes, the spiral is removed from the liquid air, and the presence of the liquefied hydrocarbons demonstrated by allowing them to volatilise; when they continue burning with a smoky flame after the stream of coal gas is cut off.]

Liquid air and liquid hydrogen may be employed to produce a high degree of exhaustion in a sealed vessel. For this purpose it is necessary that the vessel should be filled with a gas or vapour that is condensed at the low temperature attained by the use of these reagents. If, for instance, the air originally in the vessel is displaced by steam, it is easy to obtain a vacuum sufficiently good

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[1] A concise account of these problems may be found in an essay by Miss Agnes M. Clerke on Low Temperature Research at the Royal Institution, Proceedings, No. 95, p. 699.

to show fluorescence in an attached vacuum tube. Another method is to fill the vessel with carbonic acid gas, which is solidified at the temperature of liquid air. (Vacuum tubes exhausted in this manner were exhibited).

Although these methods may be of service in particular cases the practical difficulties involved in getting rid of the last traces of air and in filling the vessel with the pure gas or vapour to be employed are considerable. If liquid hydrogen is available it is only necessary to immerse in it a small bulb attached to the vessel to speedily condense all the air and obtain a very high vacuum.

DEWAR'S METHOD OF PRODUCING HIGH VACUA.

It has long been known that charcoal, freed from gas by heating to redness, is capable of absorbing gases in large quantities. The subject was first investigated by Saussure, and a detailed examination of this property of charcoal was made by Hunter (*Phil. Mag.*, series 4, 25 p. 364, 1863 and 29, p. 116, 1865). Of all the charcoals he examined, that made from the cocoanut had by far the greatest absorbing power, one volume of the charcoal absorbing 171·7 volumes of ammonia, 17·9 of oxygen, 15·2 of nitrogen, and 4·4 of hydrogen. In 1875 Professor Dewar employed this property of charcoal to improve the vacuum in a vessel exhausted by a mercury pump. His recent discovery that when the charcoal is cooled to the low temperatures now available, it is capable of absorbing still larger quantities of gas, is of great importance. This result promises to be of the greatest service in scientific research, and it is even possible that it may have important commercial applications.

[The amount of air that could be absorbed by charcoal at the temperature of liquid air was shown by the following experiment. A small bulb blown at the end of a piece of glass tubing, containing 2 grams of charcoal, was left immersed in liquid air for ten minutes. Then it was removed, and the open end of the tube place under an inverted glass receiver filled with coloured water, so that as the temperature rose the gas expelled could be collected. Over 100 c.c. of air were collected in the receiver in the course of a few minutes.

A further experiment was carried out to show that the cold charcoal was capable of absorbing air at low pressures as well as at the ordinary pressure of the atmosphere. Two similar bulbs

were attached to vertical glass tubes dipping into a vessel of mercury. One bulb was empty, the other contained charcoal. Both bulbs were cooled with liquid air. The mercury rose in the tube attached to the empty bulb to a certain height, in consequence of the contraction of the air on cooling. The apparatus, in fact, behaved as a constant volume air theremometer. In the tube attached to the charcoal bulb the mercury quickly rose to the full barometric height, showing that practically the whole of the air in the bulb had been absorbed by the charcoal.]

Sir James Dewar has described experiments to test the amount of exhaustion reached by the use of a given weight of cocoanut charcoal. He found that 30 grams, cooled to the temperature of liquid air absorbed so much air that the pressure in an electric discharge tube of 1300 c.c. capacity fell from 760 to 50 mm. of mercury. Starting with the tube initially at half an atmosphere, the exhaustion reached was now beyond the striae stage. A further experiment starting with one-fourth of an atmosphere gave a vacuum through which no discharge passed.

Experiments carried out by Lord Blythswood and myself show that it is only necessary to increase the size of the charcoal bulb in order to produce a high degree of exhaustion in a large discharge tube without the use of a pump. The first attempt I made (Jan. 30, 1905) was to exhaust an old X-ray bulb, three inches in diameter (capacity 250 c.c.). This was attached to a drying tube containing phosphorus pentoxide, and to a bulb of capacity 200 c.c. containing about 65 grams of charcoal. The apparatus was set aside for some days before it was used, so that the air might be dried. Before the charcoal bulb was cooled both it and the discharge tube were heated strongly to drive off as much gas as possible. The apparatus was then sealed, and when the charcoal bulb was sufficiently cool, it was placed in liquid air. During the process of exhaustion the focus tube was heated, and during the later stages the discharge was passed through the tube to drive off gas from the electrodes. The tube was sealed off after the charcoal had been cooled for one hour, and the vacuum produced was so good that the tube had to be heated in order to allow the discharge to pass through it.

A second focus tube, four inches in diameter (capacity 675 c.c.) was successfully exhausted with the same charcoal bulb, Jan. 31.

In the next experiment the drying tube was discarded altogether and a new X-ray bulb, five inches in diameter (capacity 1150 c.c.)

was attached to the charcoal absorber. The following notes show the progress of the exhaustion :—

11.25 a.m.	Commenced to heat discharge tube and charcoal.
11.35 ,,	Apparatus sealed.
11.45 ,,	Charcoal bulb placed in liquid air.
11.50 ,,	Discharge begins to pass.
12 noon	Both electrodes covered with a velvet glow.
12.7 p.m.	Discharge fills the whole bulb.
12.9 ,,	Some green fluorescence.
12.12 ,,	Shadow of the electrodes thrown on the tube by cathode rays.
12.30 ,,	X-rays beginning.
12.58 ,,	Discharge tube sealed off.

The result of this experiment was a somewhat "soft" X-ray tube. [A similar X-ray tube, 5 inches in diameter, was exhausted during the course of the lecture. After the charcoal bulb had been immersed for one hour in liquid air the tube was giving X-rays in sufficient quantity to be visible to the audience, though they were not of a very penetrating character.]

The results here recorded are sufficient to show that Dewar's method gives to scientific workers a new and powerful method for the production of high vacua. All complications of apparatus are done away with, drying tubes may be dispensed with, and the ease and certainty with which the process is carried out will recommend it to anyone who has had experience of mercury pumps. In exhausting Geissler tubes for spectroscopic analysis there is a great advantage in the fact that no mercury vapour is present to complicate the spectrum.

In a lecture "On the National Importance of studying Abstract Science" delivered in 1852, Professor Playfair demonstrated "the dependence of practical results upon abstract investigations." (*Phil. Mag.* (4) 3, p. 63). In these results of Sir James Dewar we have yet further proof—if that were needed—of the fact that "Discoveries, apparently the most remote and unpromising, have resulted in the most important practical issues.

"These were results unsought for; they are the necessary offshoots of abstract investigation."

In conclusion I wish to express my gratitude to Lord Blythswood for enabling me to bring before the Society this account of the work carried on in his laboratory.

CENTENARY LECTURES, No. VII.

Progress of Astronomy in the Nineteenth Century. By LUDWIG BECKER, Ph.D., Professor of Astronomy in the University of Glasgow.

[Prepared by request of the Council and delivered before the Society, 8th February, 1905.]

THE SOLAR SYSTEM.

Astronomy of Position.—About the end of the seventeenth century Newton had established the principle of gravitation. He had detected the action of this property of matter in the motion of the bodies of the solar system, and had accounted for almost all the irregularities which observations had disclosed in the elliptic motion. But observations alone cannot reveal the multitude of irregularities or perturbations we now know to exist, and it is exact knowledge of them which enables one to predict the position of a planet at all times.

Ever since the time of Newton it has been the principal problem of Gravitational Astronomy to derive theoretically from the law of gravitation these perturbations as depending on the constants which define the motion in a Keplerian ellipse. A hundred years ago the solution of the problem had, thanks to the labours of the most brilliant mathematicians of the eighteenth century, so far advanced, that the positions of the larger planets could be predicted with a tolerable degree of accuracy. It had further been shown that comets obeyed the law of gravitation; a proof had been given that the solar system is stable if only gravitational forces be taken into account, the tidal phenomenon had been studied and the motion of the earth's axis of rotation had been analytically derived. The methods employed in the calculation of the position of a planet were, however, deficient in this respect, that they still employed certain perturbations the numerical values of which were directly determined from observations. In the nineteenth century this has been remedied, and we now possess methods, which though not perfect meet our present demands.

All the methods by which our present tables of the bodies of the solar system have been constructed, determine by a process of gradual approximation the differences of the actual path of the body and the motion in an elliptic orbit. They all have the disadvantage, that in some cases the successive approximations are very slow and even illusory. Methods are now coming to the front in which the fundamental orbit takes into account the main part of the attraction of the perturbing mass, and their practical application has proved their superiority over the older methods. At the beginning of the past century there existed several discordances between the observations and the theoretical places of the bodies of the solar system as deduced solely from the Newtonian law of gravitation. All these except one have disappeared in consequence of a more rigorous mathematical treatment, and only the motion of the perihelion of the planet Mercury remains to be explained. In this case there is reason to believe that the discordance is the effect of forces not taken into account, and possibly due to attractions of small unknown planets, or to a ring of meteorites in the neighbourhood of the planet's orbit.

The most striking event in the domain of Gravitational Astronomy was the discovery about the middle of the century of the most remote planet Neptune. To the six planets known since antiquity Uranus was added in 1781. When its orbit was calculated and the journals of star observations were searched for former observations of this star-like object, it was found that the planet had been frequently observed since 1690 and several times it had escaped discovery owing to untidy book-keeping of the observers. Thanks to these early observations the orbit of Uranus could be calculated forthwith, with a precision which rivalled that of the older planets. The calculated places began soon to differ from the observations, and in 1840 the error of the theoretical position amounted to about a fifteenth of the moon's diameter. Several astronomers ascribed the discrepancy to perturbations exerted on Uranus by an unknown planet. It was argued that the unknown planet must move in an orbit which lies outside that of Uranus and at not too great a distance, because, otherwise it would perturb the motion of Uranus' neighbour, and of this there was no trace. One considered as a likely distance that given by Bode's empirical law, which placed the unknown planet almost twice as far from the sun as Uranus. Adams and

Leverrier, independantly of each other, set themselves the task to find the orbit, the position in the orbit and the mass of the unknown perturber from the observed irregularities in the motion of Uranus, both assuming that its distance was in conformity with the empirical law. Whereas in the theory of perturbations the known elements of the orbit determine the perturbations, in this case the problem is reversed. The solution of the equations in which the unknowns are involved, presented the great difficulty. The two astronomers arrived practically at the same result, and on the first night the particular region of the heavens was compared with an accurate star-chart the planet was discovered.

There is no parallel in the history of Astronomy to the theoretical discovery of Neptune. During the century many new members have been added to the known bodies of the solar system, but in every instance the objects have been detected through their motions with reference to the stars. All these are faint objects invisible to the unaided eye, and the majority are only discernible in the most powerful telescopes.

A hundred years ago three planets besides the earth were known to have satellite systems; now we know five such systems and the number of attendants of Jupiter, Saturn and Uranus has increased from fourteen to twenty, two of which were recently discovered by means of photography. Not to speak of the inspiring sight which the systems present in the telescope, their chief interest lies in the study of their motion. They have furnished Gravitational Astronomy with suggestive problems and provided the means for accurate determinations of the masses of the planets. The ring system of Saturn has formed the object of several important investigations, which prove that it must consist of swarms of solid separate particles, an immense number of small satellites, each pursuing its own independent orbit round the planet like a moon. All the satellites except the moon and the few more distant satellites, move nearly in the plane of their planet's equator, a peculiarity which has been explained by the attraction of the satellites by the protuberant matter on the planet's equator. Phœbe, the furthermost of Saturn's nine satellites, whose discovery in 1898 was until recently doubtful, has the unique property that it revolves in an opposite direction to that of the planet's rotation. How this can be reconciled with the accepted theory of evolution of the solar system remains to be shown. The satellites of Mars, both only five miles in diameter as deter-

mined from photometric observations, offer singular phenomena. The inner satellite revolves in less than a third of the Martian day, and thus it rises in the West and passes the meridian twice a day. The outer satellite has a period which is a fourth longer than the day on Mars. Consequently it moves slowly with reference to a meridian on Mars, causing it to remain two-and-a-half days continuously above the horizon, during which time it runs twice through its phases.

The empirical law of distances of the planets demands that there should be a planet in the wide gap between Mars and Jupiter. The belief in this law became greatly strengthened when the discovery of Uranus in 1781 showed its distance to conform to the law. Search was made for the missing planet but without success. By mere chance the planet was afterwards found, appearing like a faint star invisible to the naked eye on the first night of the nineteenth century by an astronomer engaged in forming a Catalogue of Stars. It was an eventful discovery when in the following year another small planet was discovered almost at the same distance from the sun, soon succeeded by a third, which gave rise to the hypothesis that these small planets, which are less than 500 miles in diameter, formed parts of a planet which had disintegrated. Astronomers began arduously to search for other fragments, with the result that in 1846 their number had grown to eight. Since that time not a year has passed without the discovery of from one to thirty of these small bodies. The searching operations were, at first, laborious and tedious. Charts were prepared containing all the stars visible in a telescope, and from time to time they were compared with the heavens. When an additional star-like object appeared, a few hours watching decided whether it moved or not, viz., whether it was a planet or a variable star. Of late years a more speedy method has been in vogue. A large portion of the sky is photographed during several hours while the telescope is kept steady on the stars by means of accurate clock work. On the negative the stars appear as dots, while a planet, if present, will make a streak instead of a dot on account of its motion relative to the stars. As many as three new planets have been found in this way on one plate. The total number is at present 556. The number not discovered is probably enormous, but it is certain that all those exceeding fifty miles in diameter are now in our list. There is no traceable perturbation in the motion of the planet Mars produced by the

total of the asteroids, which makes it certain that their combined mass cannot be one thousandth that of the earth. As to their origin, the view is generally accepted that originally they formed rings like those of Saturn and that the powerful attraction of Jupiter has disintegrated the ring. The advent of the minor planets has had far reaching influence on most branches of Astronomy. They gave rise to classical researches on the determination of orbits, and caused the development along new lines of the theory of perturbations, requiring methods suitable for large inclinations and large eccentricities of the orbits, and great approaches to the perturbing mass. In Stellar Astronomy they gave an impetus to the formation of extensive star-charts and to the observations of stars, and contributed to the discovery of variable stars. Nevertheless, when year after year new minor planets were added to the list the feeling grew that Astronomy could not benefit any more by new discoveries and that the energies employed on them should be transferred to other branches of the science.

The discovery of the planet Eros in 1898 has, however, reconciled astronomers to these troublesome objects. This planet turned out to come periodically nearer to the earth than any other planet, Mars and Venus included. At its nearest approach it is only at half the minimum distance of Venus. It therefore affords the best means for finding the distance of the sun from the earth in terrestrial units of length. In the same way as a near object appears at different places on a distant background when viewed from different standpoints, so the planet will have different positions amongst the stars at stations far apart on the earth. For instance, assume that Eros stands at one station exactly in the direction of a star, then at another station it will be at some angular distance from this star, and this angle equals the angular distance of the two stations as they appear from Eros. The distance of the stations being known in miles from the known dimensions of the earth, the distance of Eros from the earth's centre can be calculated in miles. This same distance is, however, obtained by the theory of gravitation in units of the mean distance of the earth from the sun, because Earth as well as Eros is a planet moving round the sun, and consequently the distance of the sun from us can be found in miles. In practice not one but many stars are used as points of reference, and photographs are taken at a great number of stations. There is

this great advantage in employing an outer planet as compared with the inner planet Venus, that being always luminous the photographs may be repeated during several weeks as often as the weather permits. On the other hand, the hemisphere of the planet Venus facing the earth is not illuminated when nearest to us and can then only become visible when it is projected on the solar disk, a phenomenon which may occur twice in a century; on these rare occasions observations are restricted to the few hours during which the transit lasts. It is noteworthy that the opposition of Eros in 1902 has given a much more accurate figure for the distance of the sun than the transits of Venus in 1874 and 1882. A hundred years ago the error of the distance was about three per cent., now it is less than one per thousand.

In connection with this problem it may be stated that the dimensions of the earth are now known from direct measurements with such accuracy that the calculated distance of a point on its surface and of any point on the opposite hemisphere is uncertain by less than a fifth of a mile, against ten times that amount a hundred years ago. It is impossible to give in a few words an idea of how much work had to be spent and what ingenious processes had to be invented to advance the knowledge of the earth's dimensions to such perfection.

Closely connected with the advancement of Theoretical Astronomy is that of Observational Astronomy, each increase in the accuracy of observations calling for refinement of the theory and *vice versa.* It is principally due to this dependence that the art of observing, the science of reduction of observations and the manufacture of measuring appliances have improved so much since the middle of the eighteenth century. Observations are made in an ever changing atmosphere and at the surface of a moving earth whose axis of rotation continuously alters its direction in space. To make comparable observations which belong to different epochs corrections have to be applied to the observed quantities, and it is the knowledge of these corrections which has been brought to great perfection since 1800. With their aid the intrinsically good observations of the second half of the eighteenth century have been reduced again and they have become more valuable.

The discovery in the year 1887 of the motion of the axis of rotation of the earth with reference to its surface may serve as an illustration of the accuracy now attainable. During the past ten years a continuous series of observations has been made at

stations distributed over the earth, and they have fixed, with reference to a fixed North pole on the earth's surface the point on the earth's surface where the axis of rotation pierces the surface. These positions are accurate to about five feet. They lie along a path which though apparently erratic can be represented by a simple mathematical formula. The determination of this path rests on the following consideration. The geographical latitudes of two stations *A* and *B*, which differ 180 degrees in longitude, are measured from star observations. After an interval of time, let the axis of rotation have shifted on the earth towards *A* to the amount of a second, then the latitude of *A* will be found a second greater and that of *B* a second smaller than before, while stations 90 degrees from them in longitude will disclose no changes in their latitudes. This phenomenon is, of course, quite different from the displacement in space of the axis of rotation, which merely makes the axis show towards a different star and is the same for all places on the earth. The cause of the change of latitude has not been found. Theoretically any alteration in the arrangement of the matter of the earth, such for instance as is produced by air currents must disturb the axis and derange the latitudes. But whereas the theoretical period in which the axis moves round the pole point is 301 days, the movement as actually observed is composed of two motions, one an annual revolution in an ellipse of about thirty feet across, the other in a circle of about 26 feet in diameter at a period of 428 days. The latter period has hitherto been the stumbling-block of all theories.

Physical condition of the Sun.—The great advance of Physical Science in the nineteenth century has opened a new field to Astronomy. Until the middle of the century the study of the Universe rested entirely on eye-observations with the telescope, while the composition of sun and stars was outside the range of exact knowledge. By the aid of the spectroscope we now examine the chemical nature of celestial objects, we measure the rates of their motion in terrestrial units of length, and obtain data from which we may speculate about their origin, development and decay. Delicate appliances for measuring heat and light radiations reveal the physical conditions, photography records what is beyond the range of the human eye, and in some cases enables us to accomplish in a few hours what by the old methods would have meant the expenditure of years of work. Before I relate the present

day views on the physical state of the solar system, I think it would not be amiss to shortly detail the principles of spectroscopy.

Light consists of vibrations of different periods, and the vibrations of a certain period produce in the eye a certain sensation of colour. The period of violet rays is, for instance, only about half of that of the red rays. A beam of light which is emitted from a luminous source is, as a rule, complex, it contains vibrations of a great number of different periods. To separate a beam of light into its constituent parts we let it pass through a small opening and then through a prism, which refracts rays of different periods in different ways. Instead of one beam of light we have then as many as there are constituents. We place a lens in the path of the rays. Without the prism we obtain one image of the opening, with the prism a series of images each one belonging to a vibration of a certain period. The total of these images is called the spectrum, and the opening, the prism and the lens constitute the spectroscope. As a rule, we do not employ a round opening for reducing the beam of light to a suitable section, but a fine slit the images of which are, of course, fine lines, the so-called spectral lines. Experiments have shown that the spectrum of luminous solids or fluids is continuous, and they therefore send out light, which consists of vibrations of a continuous series of periods. On the other hand the spectrum of gases or vapours is discontinuous, at least if the density is not high. In the case of sodium there are found in the spectrum only two very bright lines in the yellow region besides a number of fainter ones, while for iron the number reaches several thousands. Now let us place luminous sodium vapour in front of a hot luminous solid, so that the rays from the solid pass through the sodium vapour. The effect is a continuous spectrum in which there are dark lines at the places where the sodium vapour alone would produce bright lines. These dark lines are by no means black, they appear dark by contrast with the bright continuous spectrum, and they are even brighter than the bright lines which the sodium alone produces. What really takes place is this. The vapour absorbs to a certain extent only those rays which it is capable of emitting at the same temperature. Thus at places where sodium vapour does not produce a spectral line, the continuous spectrum of the solid will be unchanged, while at those places where sodium has a spectral line the intensity will be that of the continuous spectrum of the solid, reduced by

absorption in the sodium, and augmented by the radiation of sodium itself. If the sodium or vapour radiation does not make up the loss in intensity of the rays from the solid there will be a dark line in the spectrum, otherwise a bright line. In every case where dark spectral lines are produced in a bright continuous spectrum, it is certain that light from a luminous solid or liquid passes through an atmosphere of gases, which by themselves would give bright lines at the places where the dark lines occur. Now the light from the sun gives a continuous spectrum with a great number of dark lines, and we come to the conclusion that the light is emitted by luminous solid or liquid particles, which form the so-called *photosphere*, while the dark lines are due to an atmosphere, which would by itself produce a bright line spectrum exactly at the same places where the dark lines are observed. Spectra of the gases of all the terrestrial elements have been artificially produced by means of heating in flames or in the electric arc and spark. Comparison of them with the dark lines of the solar spectrum has taught us that most terrestrial elements are present in the gaseous state in the sun's atmosphere. The heaviest metals of atomic weight greater than 180 are not found except lead and uranium and most of the metalloids. I shall refer to them again.

Physical Science provides the means for determining the temperature of the surface of the sun. We can measure the quantity of the sun's heat which falls on a certain area on the earth and compare it with the heat radiated from a body of known temperature. On the assumption that the photosphere of the sun is a perfect radiator its temperature comes out at 6,000 degrees Centigrade, which is in fair agreement with that calculated from the position of maximum intensity in the solar spectrum; fifty years ago the temperature was considered very much higher, several million degrees. In the last ten years we have also learnt how to determine the pressure in the solar atmosphere. According to laboratory experiments the position of a line in the spectrum is slightly changed with increasing pressure, and based on these results a pressure of five atmospheres is calculated from the displacement of the lines of the solar spectrum. This pressure belongs to the base of the solar atmosphere immediately above the photosphere, where the reversals of the spectral lines take place. The average density of the gases at this level comes out at less than a thousandth of the density of water, whereas the

average density of the whole sun which is obtained from the ratio of the masses of Sun and Earth, and the density of the Earth is one and a half times that of water. Theories of heat and gravitation then tell us that temperature and pressure increase towards the centre, and that perhaps the whole body of the sun is gaseous, because the temperature is far beyond the critical temperature of those gases which occur in the solar atmosphere.

A hundred years ago a great authority described the sun as a cool dark solid globe protected by a heavy cloud-canopy from the glare of the upper luminous region where the solar Aurora, some thousands of miles in depth, evolves the store of light and heat which vivify our world.

From the data given and the known gravitation at the surface of the sun, physical science would be able to deduce the conditions prevailing in the interior of the sun, if the laws which govern the behaviour of gases at high temperatures and pressures were known. The known laws, however, belong to conditions which can be realised in the laboratory, to temperatures and pressures which are far below those that must occur in the interior of the sun. All that may be expected from a judicious application of these laws is some kind of an idea of the order of magnitude of the pressure and temperature at the different levels.

I now proceed to explain one of the modern theories of the sun, and in connection with it to relate observational facts which have led to the theory.

The whole body of the sun is considered to be in a gaseous state, pressure and temperature steadily increasing inwards towards the centre of the gaseous sphere. At the centre the temperature must be counted by millions of degrees, and pressure may be of the order of thousands of millions of atmospheres. The density at the centre may be ten times that of water. Owing to the great internal friction of the gases at such high temperatures and pressures, it is believed that the consistency may resemble that of a liquid. At the level of the sun's visible outline the pressure is about five atmospheres. At this level the conditions are such as to favour the formation of clouds, which float in the gaseous mass in the same way as clouds in our own atmosphere. Perhaps the clouds are solid carbon. The sheet of clouds which is called the *photosphere* forms the visible surface of the sun, from which we receive almost entirely our heat and light. The particles, liquid or solid, constituting the clouds cool

in consequence of radiation and sink into the gases below. Convection currents from lower down, or explosions in the lower strata, carry new gases upwards, and cooling by expansion some of their constituents condense and thus renew the photosphere.

The theory well accounts for the appearance of the sun in the telescope and on photographs. On photographs the photosphere is not uniformly bright but spotted; brilliantly white grains are distributed on a much darker background. They measure some hundreds of miles across, and probably are the clouds not yet cooled by radiation. Their temperature must exceed the average temperature of 6,000 degrees, as determined from the radiation we receive, whereas the darker clouds must be cooler. The range of temperature in the photosphere probably exceeds 1,500 degrees. The assumption that the temperature of the photospheric clouds decreases with the height, would account for the falling off of the intensity of the sun's light from the centre towards the edge of the disk. Similar grains which completely outshine the grains of the photosphere are seen in the neighbourhood of the sunspots. These bright grains, the *faculæ*, are also clouds, and though much hotter than the photosphere are high above it in the solar atmosphere as I shall prove.

The gases of the solar atmosphere in the vicinity of the photospheric cloud sheet are about as hot as the photosphere but become cooler with increased height. They are not by far so luminous as the photosphere, for the same reason that a metal wire heated in a Bunsen flame appears bright in the darkish flame, or in other words, such heated gases emit much less light than a perfect radiator at the same temperature. Even the sunlight reflected by the sky outshines these gases, and thus hides the solar atmosphere on ordinary occasions. At a solar eclipse at the moment when the sun's disk has just been obscured by the moon and thus the sunlight has been shut off from our atmosphere, the solar atmosphere appears as a very narrow bright crescent of reddish colour which gradually fades into the white *Corona*. At the base of the corona, that is at the outer edge of the red crescent, the pressure is not much more than a thousandth of an atmosphere.

In the gaseous mass which constitutes the sun and its atmosphere, the gases with small molecular weight must extend further than the heavier ones. This behaviour is incomparably more pronounced in the sun than in the earth's atmosphere,

considering that the radius of this gaseous mass is more than a thousand times the height of our atmosphere, and gravity at the level of the photosphere about twenty eight times that at the surface of the earth. Observations bear this out. At the instant when the moon has just covered the solar disk or the photosphere, the solar atmosphere is left visible as a crescent. It is easily proved that the cusps of the crescent belong to the highest levels of the solar atmosphere. Photographed through a prism a series of bright images of the crescent are produced corresponding in position with some of the dark lines of the solar spectrum. On a grand scale we have here a verification of what has been learned from laboratory experiments. All such photographs of the spectrum of the solar atmosphere contain large and small crescents. The cusps of the long crescents belong, as I have pointed out, to a higher level of the atmosphere than those of the shorter ones, indicating that the gases Hydrogen, Helium and Calcium, to which these long crescents belong, extend further into the atmosphere than the metal gases. Beyond the cusps of the largest crescents some photographs show narrow bands, the continuous spectrum of solid or fluid particles, which must be due to detached clouds at a very high level in the solar atmosphere : these are the *faculæ* mentioned before. In line with their continuous spectrum you will notice in the spectrum thrown on the screen bright detached spots, most of them seemingly a continuation of the larger crescents, which prove, that at a height in the solar atmosphere where it does not generally give a spectrum for a short exposure, a hot mass of Hydrogen and Calcium is embedded in a cooler atmosphere in the vicinity of the faculæ clouds. These hot gases form the top of prominences as was ascertained from other photographs.

The phenomenon just described lasts for about three seconds, during which time 700 miles of the solar atmosphere are covered by the moon. After these three seconds most of the metallic lines fade, and there remain principally those of Hydrogen, Helium and Calcium. They also cease to be noticeable when a further 4000 miles of the atmosphere, or a hundredth part of the sun's diameter has been covered by the moon, and it is at this level where we have to place the faculæ. From the longer perseverance of the lines of lighter gases as compared with those of the metal gases it cannot be argued that the metals which constitute the lower stratum of the atmosphere, which is called

the *chromosphere*, are absent, but only that their density in the higher strata is too low to produce a sufficiently strong spectrum. Now, gases of the same molecular weight do not give spectra of the same intensity. This explains why Calcium, which as we know, is discernible in the minutest quantities, can be traced to the same level as the light gases, Hydrogen and Helium, and why Strontium and Barium, which strongly radiate light, are the only heavier metals represented in the spectrum of the chromosphere. It may be assumed that though the heaviest metals be present in the sun, their density above the level of the photospheric clouds may not be sufficient to give a spectrum.

As to metalloids we know that they radiate and absorb very little light when merely heated, and the same refers to their compounds. They might be present in the sun and yet their lines of absorption would differ so little in intensity from the light of the continuous spectrum that they might escape detection. Helium gives an example in point. The absorption lines are absent in the solar spectrum, whereas on the occasion of an eclipse the gas has been shown to extend to the highest strata of the sun's atmosphere. It must be borne in mind that at the time of an eclipse we look through the solar atmosphere along a tangent to the sun's surface and receive thus light from a depth of Helium which is many times as great as that traversed by the rays when we observe the solar spectrum.

While in case of metalloids it is the want of radiating and absorbing power which might cause their lines to be invisible or faint in the solar spectrum, the radiations from metallic gases immediately above the photosphere can be so strong that they supply almost as much light as they absorb of the light of the continuous spectrum of the photosphere, and thus make the spectral lines invisible. Now, when the moon eclipses the sun a number of bright spectral lines appear which have no corresponding dark lines in the solar spectrum, and they are known to belong to metals which are intensely heated. Obviously they originate in the hottest layers of the atmosphere in the immediate neighbourhood of the photosphere.

There are two phenomena observed on the sun, prominences and sunspots, which when more studied than they are at present, may give us an insight into the constitution of the sun below the photosphere.

At a total eclipse of the sun, there are seen at the edge of the

moon's disk a number of scarlet points, which in the telescope appear like bright red clouds. These, the *prominences*, were until the middle of the century believed to be appendices of the moon. According to spectroscopic observations all the elements which are in the solar atmosphere compose such a prominence, but they are at a higher temperature. Metal vapours are principally near the base of the prominence, they become rarer with the height, and at the top generally only Hydrogen, Helium, Calcium and the hypothetical element Coronium, which extends into the Corona are found. The gaseous prominences are not by far so bright as the solid or liquid photosphere, and their light is even drowned out by the light of our sky near the sun. The spectrum of our atmosphere, which is continuous similar to that of sunlight, can be made faint by great dispersion, whereas the brightness of the bright lines of a prominence is not affected by dispersion. Thus if we place the slit of a spectroscope tangential to the sun's edge a prominence will be seen in its actual form at every spectral line which is bright in the prominence spectrum. Fifty years ago prominences could only be observed at a total solar eclipse. These prominences are ordinarily not very large; at times they become enormous, and once a prominence was seen to reach 400,000 miles above the photosphere, which is one hundred times the height at which the solar atmosphere gives a spectrum, and half the diameter of the sun. They are always changing in form, often with such rapidity that the changes involve velocities of at least 250 miles per second in the moving gases. The estimate of the velocity rests here on a change of form in a given time and it can but be approximate, because the paths of the elements are not perceptible.

The spectroscope, however, enables us to determine the velocity in the line of sight from only one observation with the greatest accuracy. Every one must have noticed that the pitch of an engine whistle suddenly drops when a whistling engine passes and recedes. Careful experiments have proved the drop in the pitch to be proportional to the velocity at which the engine moves away no matter whether the engine or the observer is moving. In the same way a light-ray has its period of vibration increased when the source of light moves away from us, diminished when it approaches. This change of period entails a change in position of the spectral lines, and the amount of displacement in unit of the wave-length equals the ratio of the

unknown velocity and the velocity of light. Our refined instruments and the application of photography now allow us to determine velocities in the line of sight with an accuracy of less than half a mile per second, no matter at what distance the object be from us. The principle is illustrated on the screen. The lower strip is a piece of the yellow portion of the spectrum of a star containing the conspicuous dark lines of sodium. Above is the corresponding part of the spectrum of a flame containing sodium vapour. Were the star at rest, the sodium lines would have exactly the same position in both. Here the star lines are displaced by a quarter of the distance of the sodium lines, or about one four-thousandth of the wave-length of sodium. The star is therefore moving at one four-thousandth the velocity of light, therefore, fifty miles per second; its motion being towards us, because the lines are displaced towards the blue end of the spectrum. On the screen you see the effect of the motion of the gases of a prominence on one of the bright blue lines of Calcium. The prominence lies near the centre of the sun's disk, the slit being placed across it. If the gas in the prominence were at rest the image of the narrow slit in the light of the prominence would be a bright narrow line at the place of the prominent dark line of the solar spectrum. Now, particles moving towards us have their lines displaced towards one side, those moving away towards the other side, and the displacement is greatest for the fastest motion. The highest velocity is in this case 250 miles per second. You see that all velocities from zero up to plus or minus 250 miles are represented, just what one should expect from a gaseous mass rushing away from the sun and falling back towards it.

Sunspots are conspicuous objects on the solar surface. There have been spots which measured only 500 miles across, and again others with a diameter as great as 50,000 miles, or including the fringe, 150,000 miles.

A sunspot appears dark by contrast with the bright faculæ and photosphere. Though more brilliant than lime-light its brightness is only a hundredth of that of the photosphere. The faintness of the spot cannot be due to a cloud of solid or liquid particles high up in the solar atmosphere, shutting off the light of the photosphere, because, owing to radiation from the photosphere the temperature, and consequently the luminosity of the cloud particles would almost be that of the photosphere. At a sunspot

the photosphere is removed, and we are looking through a clear atmosphere into the gaseous interior of the sun. A great depth of gas of uniform temperature throughout, radiates as intensely as a perfect radiator at the same temperature, with this difference, however, that while a perfect radiator emits radiation of all wave-lengths, the gas sends only those of certain wave lengths. Each spectral line of such a gas will be as brilliant as the continuous spectrum of a solid at the same temperature. Increase of density broadens the spectral lines and thus increases the number of wave lengths at which the gas is capable of emitting light. Though it is by no means certain that with increased density all radiations should be emitted, the effect of an unlimited depth of gas of great density will be a spectrum almost continuous, which is as bright as that of a perfect radiator at the same temperature. Rays which have to traverse a certain height of the column of the gas will be entirely absorbed, and thus only the upper layers contribute to the radiation we receive. The same holds good when temperature and pressure continually increase inwards, because the power of absorption is almost independent of temperature, therefore the sun's interior shining through an opening in the photosphere will appear as bright as a perfect radiator at the temperature of the layers which contribute to the radiation. These layers being near the photosphere, a sunspot should appear about as bright as the photosphere. To explain the darkness of the spot we are forced to assume that in a sunspot the dense gases, which send us the continuous spectrum are at a temperature which is below that of the solid or liquid particles of the photospheric cloud, about 3,000 degrees, as compared with the average of 6,000 degrees of the photosphere. This low temperature would account for the extreme faintness of the blue end of the sunspot spectrum.

The sunspot spectrum, the yellow region of which is thrown on the screen, was obtained by having the slit placed across the spot and the photosphere. Top and bottom give the ordinary solar spectrum and the dark central band belongs to the spot. There are sharp absorption lines at the same places in the spot spectrum as in the spectrum of the photosphere, and most of the metallic lines are widened, proving that the atmosphere above the dense gaseous layers which give the continuous spectrum, is similarly constituted to the atmosphere above the photosphere, but it is considerably denser at its base. For this reason we should

seek these dense cold layers not high up in the solar atmosphere, but in the neighbourhood of and perhaps below the photosphere. The sharpness of the lines indicates change in the pressure gradient of the gases or a different chemical constitution of atmosphere and dense layer.

The appearance of the Hydrogen lines is also suggestive. Hydrogen lines do widen since they are among the broadest lines of the solar spectrum, and yet, unlike the metallic lines, their breadth is not increased in the sunspot spectrum. It appears that there is not more nor denser Hydrogen in the atmosphere of a sunspot than above the photosphere, and therefore the conditions below the level of the photosphere cannot be such that the Hydrogen molecule can exist there. What becomes of the Hydrogen molecule which gravitates below the photosphere of the sun? It is either absorbed or it enters into chemical combination with other molecules.

There is one other peculiarity in a sunspot spectrum which a theory on the nature of these phenomena must take into account. Some absorption lines, especially those of Hydrogen and the lighter metals Sodium and Calcium, frequently show a sharp bright line, sometimes of considerable breadth, in the middle of the dark line, and this proves that in the upper reaches of the atmosphere of a sunspot, the gases must be more heated than in the denser layers immediately below. I show on the screen one of the Hydrogen lines of the spectrum of a sunspot, which exhibits what has been described. You further see the hooked line due to a prominence which starts from the centre of the sunspot at great velocity, and bending away from it gradually comes to rest.

The theory utilises these results. All kinds of chemical combinations are considered to be possible in the interior of the sun. Chemical compounds are mixed in the gaseous state and are in chemical equilibrium, which adapts itself to the changing pressure and temperature. When the pressure increases such combinations are formed as take up a smaller volume, and when the temperature increases combinations come into existence which absorb heat in their production. It is argued that the heat of combination is incomparably greater at the temperatures which are counted by thousands of degrees than for the temperatures realisable on the earth, and that they must play an important part in maintaining the temperature of the sun. According to

this view the chemical energy probably exceeds by far the mechanical, to which hitherto alone the constancy of the solar radiation has been attributed. If by any cause such a mixture of gases moves upwards where pressure and temperature are less, dissociation will occur resembling an explosion, because, at very high temperatures reactions take place at a great rate. Pressure and temperature will increase and further dissociation stop until the surrounding layers have been pressed aside and heated. Hydrogen, and to judge from the constitution of the earth, Carbon, are supposed to have an important part in the chemical combinations below the photosphere. On this assumption, Hydrogen, gaseous Carbon, and metals will rush towards the surface at immense velocities and give the appearance of a prominence. At a certain level above the photosphere where the gaseous mass has sufficiently cooled by expansion, Carbon will fall out in the form of clouds and produce the bright streaks which we call faculæ, and whose intensity, as I have shown on the screen, considerably exceeds that of the grains of the photosphere. The eruptions increase the gaseous pressure in the upper strata of the sun's atmosphere. They are analogous to barometric minima in our own atmosphere, and like them are accompanied by barometric maxima which are characterised by a downward motion of the gases of the atmosphere. In this downward motion they become heated owing to compression, and it is the heat thus supplied which dissolves the photospheric cloud below, in the same way as in our own atmosphere the clouds disappear at an anticyclone.

While these changes take place in the atmosphere of the sun the withdrawal by the eruption of matter from the layers below the photosphere is supposed to be followed by an inrush of the gases from the surrounding regions. On this assumption they will cool by expansion and produce that layer of cooled gases which, through the opening in the photosphere, appears to us as the dark background of the spots. Or, as an alternative, the heated gases moving downwards in the anticyclone enter into such combinations with the gaseous mass below, as absorb heat in their formation. This layer sends us the continuous spectrum, the gases above produce the dark lines, while the heated upper layers before they have spent some of their energy on the dissolving of the photosphere, cause the double reversals of the spectral lines The cycle—protuberance, faculæ, sunspot—repeats until equilib-

rium is established. Sometimes the disturbance lasts only a few days, though usually it extends over two or three weeks.

The sunspots and faculæ take, of course, part in the rotation of the sun round its axis, and for several hundred years their motion has been used to determine the position of this axis and the time of rotation. During the past century the singular fact has been disclosed, that spots which lie near the equator of the sun move fastest, completing a rotation in twenty-five days, against twenty-six-and-a-half days at a latitude of 30 degrees. No satisfactory explanation of this behaviour has as yet been given. From velocity determinations by means of the spectroscope it appears that the photospheric clouds and the faculæ share this peculiarity, and besides, that at the same latitude above the equator the photospheric cloud moves by just as much more slowly than the sunspots as the sunspots move more slowly than the faculæ. Perhaps the atmosphere rotates at a slower rate than the photosphere, and in that case, as experiments and theoretical investigations have proved, currents are produced in the atmosphere which are directed towards the poles. The observed drift of sunspots towards the poles would find on this hypothesis a natural explanation.

What we know about the distribution and frequency of the sunspots are also discoveries of the past century. For the most part sunspots and faculæ are confined to two belts between 5 and 40 degrees on the Northern and Southern hemispheres. At the sun's equator very few have been observed, and beyond latitude 40 degrees, they hardly ever occur. The number of sunspots varies greatly in different years, and shows an approximately regular periodicity of about eleven years. During the maximum the surface of the sun is never free from spots, sometimes a hundred are visible at once. During the minimum, weeks and even months pass without a single one. Many attempts have been made to connect this phenomenon in some way with planetary action, but without success, and it is now believed that the cause must be sought within the sun itself. It has often been tried to show that solar activity as measured by the number of sunspots influences the temperature, barometric pressure and rainfall on the earth. Thus far the evidence is inconclusive. One correlation between sunspots and the earth is, however, perfectly proved. When the spots are numerous, Auroras and magnetic disturbances are most numerous and intense, and in

many instances notable disturbances upon the sun have been accompanied by violent magnetic storms and brilliant exhibitions of the *Aurora Borealis.* How the connection has been explained I shall relate later on.

I have as yet not spoken of the *Corona,* the halo of whitish light which is seen to surround the sun when it is eclipsed by the moon. The portion near the sun is brighter than the full moon, but its brilliancy rapidly decreases outwards according to a certain law. Near the sun the Corona is white with a yellowish tinge, which contrasts with the narrow scarlet crescent of the solar atmosphere and the prominences, further away a tendency towards green is noticed. The Corona gives the impression of numberless rays emanating radially from the sun and bent away from the poles of the sun. Their curvature suggests a magnetic field which might be produced by the rotation round the sun's axis of electrified particles suspended in the solar atmosphere. Though the Corona of the sun always presents a different outline at different eclipses there is a strong resemblance in character among those occurring at the time of the same sunspot frequency. When there are many sunspots the rays are uniformly distributed over the circumference of the sun, and at a sunspot minimum the equatorial rays predominate.

Spectroscopic observations and measurements of the light and heat radiations have combined to give us an idea of these rays. They are made up of particles far apart compared with their size; in the neighbourhood of the sun these particles are raised by the radiation of the sun to a high temperature which can be calculated from physical laws, and is about 4,500 degrees Centigrade at a height of a fiftieth of the solar diameter above the photosphere. At these temperatures they are self luminous, their spectrum is continuous, and the ratio of the intensity of heat and light-rays is in agreement with the measurements. These latter measurements prove that at a height of a fiftieth of the solar diameter the particles cover only a two hundred thousandth part of the area on which we see them projected, which explains the faintness of the corona as compared with the sun. Further away from the sun the temperature decreases and so does the luminosity. At a certain distance the sunlight reflected by the particles begins to predominate over the emitted rays. Beyond this the corona shines essentially in reflected sunlight. This accounts for the faint solar spectrum in the outer corona, and for the fact that the

light is greatly polarised. In addition, inner as well as outer corona gives evidence of a luminous gas, traces of which have been detected two-thirds of the solar diameter above the photosphere. The substance which causes their radiation is probably much lighter than Hydrogen, considering that it has been seen twice as far from the photosphere as Hydrogen. The unknown gas has been called *Coronium.* Coronium and Hydrogen are not essential parts of the Corona. At eclipses occurring in years of sunspot minima, no trace of them was discovered in the corona, and they occur in regions near the photosphere which are bare of coronal rays. The gases occupy, no doubt, the last layers of the solar atmosphere from which the corona emerges.

It was recently explained why such small particles as constitute the corona should be expected near the sun. There are several ionizing agencies acting on the sun. It is likely that the solar eruptions are followed by cathode rays, which would ionize the gases of the atmosphere, and besides, according to laboratory experiments, solids as well as some gases emit at high temperatures, negatively charged corpuscles, a stream of which will be sent out whenever the equilibrium of the electric forces is disturbed by local elevation of temperature. It is an experimental fact that these negatively charged corpuscles have the faculty of condensing the gases through which they pass : globules will be formed of all diameters, and they will evidently consist of the elements contained in the solar atmosphere. Now there is a peculiarity of light-rays that they exert a pressure on matter which is proportional to the area of the surface on which the radiation falls, and to the intensity of the radiation. Just like gravitation this pressure decreases with the square of the distance from the sun, but while gravitation depends on the mass, the cube of the diameter, pressure of light-rays depends on the area, the square of the diameter. With decreasing diameter of a globule the force of gravitation decreases more rapidly than the pressure exerted by the light-rays, and for each density there will be a diameter of a particle for which both exactly counteract each other. In that case the moving force will be nil at all distances. For particles of smaller diameter the pressure of light-rays will predominate, for larger particles gravitation. The diameter in question can be calculated from physical laws, and it is for a particle of iron equal to about the wave-length of violet-rays.

These particles floating near the sun, their weight balanced by pressure of light-rays, are supposed to constitute the corona. Particles of greater diameter fall back into the photosphere, those of smaller diameter are pushed into space. The data given above enable us to form an idea of the quantity of matter in the corona. Particles one hundred thousandth of an inch in diameter are about 7 feet from each other in the brightest part of the corona, and 35 feet apart at a distance of one solar diameter from the surface of the sun. All the particles in the corona, no matter what they are made of, together weigh only as much as an iron ball 100 yards in diameter.

The negatively charged particles of smaller diameter are, as mentioned already, pushed into space, and form the connection between solar activity and *Auroras* and magnetic disturbances on the earth. Some of them enter the earth's atmosphere in which they are retarded in the same way as meteorites. Most of them will fall where the sun stands highest, that is in the tropics, whence they are blown by the wind currents towards the poles of the earth. In consequence of the negative charge thus given to the highest layers of the atmosphere, discharges will be produced causing cathode rays in the layers, and this is in agreement with actual observation. Cathode rays have a tendency to run parallel to the lines of force of a magnetic field. Consequently in this case they remain at greater height within the tropics than near the magnetic poles. As the visibility of the path of the cathode rays decreases with the density at a certain limit of rarefaction it becomes apparent why the aurora is mostly met with in higher latitudes. Greater activity on the sun sends an increased number of particles to meet the earth, and thus an increased number of auroras; this again is in agreement with observations. As a moving electrified body acts like an electric current, the motion of the charged particles which is due to air currents, will produce magnetic disturbances. In point of fact, a connection between magnetic disturbances and the direction of the wind in the upper strata has for some time been known to exist.

PLANETS.

Physical condition of the Planets.—Of the physical conditions of the four large planets, Jupiter, Saturn, Uranus, and Neptune, very little is known. The light they send us is reflected sunlight, and there is not the slightest evidence that they shine with their

own light. For instance, the satellites of Jupiter become invisible in the largest telescopes when they enter into the shadow of the planet. The four planets are evidently in the same condition and in some respects resemble the sun. They all have an average density smaller than that of the sun and their light reflecting power is very high, about three times that of the moon. Probably they are in a vapourous state though much cooler than the sun, and the light we receive from them is sunlight reflected by clouds floating in the atmospheres of the planets. Their atmospheres contain identical but unidentified substances, possibly chemical combinations, which show themselves by absorption-bands in the red region of the spectrum. These are especially in evidence at the darkish stripes or belts which lie parallel to the equator, and prove that the belts lie at a deeper level than the bright regions. It is generally thought that the parallel arrangement of the belts, which are perhaps clouds, is caused by the rapid rotation of the planets round their axes, the period being in each case less than half-a-day.

The behaviour of the spots on Jupiter is similar to that of the sunspots. They change rapidly in appearance and move much faster near the equator than at the higher latitudes. Of the spots on Jupiter the most remarkable is the red spot of the year 1872, which at first insignificant, became rapidly a most conspicuous object, but is now slowly dwindling. It is believed that this spot is a cooled region endowed with a slight motion of its own, and that as in the case of sunspots a current of atmospheric vapour sinks down towards it.

As to Saturn's rings I have already mentioned that for theoretical reasons the rings must be considered as formed of swarms of solid separate particles, each pursuing like a satellite its own independent orbit round the planet. The spectroscope has furnished direct proof that such is actually the case. Speaking on protuberances, I explained that a source of light in motion, from us or towards us, gives a spectrum in which all the spectral lines are displaced, and that this displacement determines the velocity of the moving source. In the case where light is reflected by a moving body such displacement is almost doubled. In an experiment recently made the slit of the spectroscope was placed across Saturn and the rings, and thus spectra were obtained of those points of the rings and planet which appear to us to lie in a straight line. The spectral points belonging to the left edge of

the planet's disk were found to be displaced towards the violet, indicating that the planet rotated towards us at the left, at exactly that velocity which is calculated from its known period of rotation. The right edge gave a displacement in the opposite direction which led to the same results. A similar measurement was made of the displacements of the points belonging to the inner ring and the outer ring. If the ring were solid the linear velocity of the inner ring would, of course, be smaller than that of the outer ring. But exactly the opposite was observed. The outer ring gave a smaller displacement than the inner ring, and the velocities derived from them were in perfect accord with those which satellites would have at the same distances from the planet.

The four smaller planets, Mercury, Venus, Earth, and Mars and our Moon, also form a group. Their mean density compared with water ranges between three-and-a-half for the Moon and five-and-a-half for the earth, and it is certain that they have a solid crust, and shine with reflected sunlight. In the early days of spectroscopy, absorption lines due to water vapour were supposed to be visible in the spectra of Mercury, Venus and Mars, but photographic spectra obtained with far more powerful instruments show no appreciable trace of water-vapour, at least for Mercury and Mars. Certainly there is considerably less water-vapour in the atmosphere of Mars along its horizon than in a vertical column of the earth's atmosphere in our climate.

The only planet of the atmosphere of which we have visual evidence is Venus, which at a transit across the sun's disk is encircled by a ring of light due to refraction in its atmosphere. Its surface is hidden from us by a dense sheet of clouds, as otherwise it would be difficult to account for the want of permanent surface markings and for the high reflecting power of Venus, which is from four to five times greater than those of Moon, Mercury and Mars. On the other hand, permanent surface-markings are very distinct on the planet Mars. Occasionally spots which lasted only for a few hours, have been observed on Mars obliterating the permanent markings. They are believed to be clouds which float in a very transparent atmosphere, much thinner than our own. The Moon has no appreciable atmosphere. If there were an atmosphere the Moon's diameter would be found too great from direct measurements, and too small when derived from the time which the Moon's disk takes to travel across a star. Both, however, are in perfect agreement. Nor in accordance with the kinetic theory of

gases could an appreciable atmosphere be expected on the Moon, because the Moon's gravity is not strong enough to retain for any length of time the molecules of the known gases. The same must apply and in a higher degree to the small planet Mercury, on which, as it is nearer to the sun, the action of the solar heat is more powerful than on the Moon.

Of the topography of Mercury there is only scanty information. Permanent markings appear, however, to have been observed of late and they have led to the conclusion that the planet turns always the same side towards the sun just as the moon does towards the earth.

Great advance has been made in the past century in the mapping of the moon. A hundred years ago the maps were but crude. Our present day maps may be said to contain correctly every hill or valley that is a mile long and half-a-mile across. They have been constructed from photographs in which the fine detail has been filled in from direct observations. The heights of the mountains have been ascertained from the length of their shadow or from the time when the sun is seen to rise on them. A curious phenomenon, unexplained as yet, is seen near and at full moon. Streaks then radiate from certain craters, in some cases many hundred miles long and appearing to pass over hill and valley.

Also on the planet Mars markings have been known for several hundred years, but it is only in the latter half of the past century that the surface has been carefully studied. The most prominent of the markings are the white patches near the planet's poles, the so-called polar caps. They dwindle in summer and grow in winter and are perhaps snow. Bluish grey and greenish patches cover almost three-eights of the planet's surface, and they are believed by some to be water, by others who have observed detail within the area and changes following the seasons they are considered to be covered with something like vegetation. More than a half of the surface has an orange shade, and this is interpreted as land. In addition to these markings, whose reality cannot be doubted, there have been mapped a great number of fine straight lines, or canals as they have been called, covering the orange coloured regions in all directions. It is a remarkable fact that some observers can hardly perceive these canals, and this group includes observers who have viewed the planet through the most powerful telescopes under the best atmospheric conditions.

The view has been advanced that these lines are optical illusions due to a tendency of the eye when there is indistinct vision, to see continuous narrow lines where in reality there are broad bands or a series of detached spots. Numerous experiments have been made to test this theory, and on the whole they favour this explanation.

The surface temperature of the four planets, Mercury, Venus, Earth and Mars, and of the Moon, depends principally on solar radiation which by far exceeds the heat conducted from the interior of the bodies. Physical laws enable us to calculate these temperatures from the known quantity of heat which the sun radiates per minute on a square foot of the earth, from the reflecting power of the planets which is known from photometric measurements, and from their distance from the sun. For the moon the temperature is 140 degrees Centigrade at a place where the sun stands overhead, and absolute zero on the hemisphere which has night: this is on the assumption, however, that the moon has no atmosphere. Actual heat measurements of the moon fully confirm these results. In the case of Venus we know that there is an atmosphere. Leaving the equalising effect of atmospheric currents out of consideration we get for the mean temperature of the side facing the sun about 50 degrees Centigrade, and for the opposite side it would be near the absolute zero. Spectroscopic observations published last year raise it beyond doubt that Venus always turns the same side towards the sun. In that case atmospheric currents would be set up carrying along with them water-vapour if it existed, portions of which would be deposited on the night side as snow. In the course of ages all water-vapour would thus disappear from the atmosphere, which is contrary to spectroscopic results. How the long period of rotation can be reconciled with the spectroscopic evidence of water-vapour remains to be explained. If Mars had no atmosphere its mean temperature would be -37 degrees, and at no place would the temperature rise above the freezing point during the 24 to 25 hours of the Martian day. What then are the white patches which melt in summer and are formed again in winter? Some have supposed that they might be solid carbonic acid. But this very assumption leads to the result, that in summer there must be a great quantity of carbonic acid gas in the atmosphere, because, the pressure of the atmosphere cannot be such as to keep it in the liquid state. Now carbonic acid gas strongly absorbs the dark

heat rays, and the effect of its presence in the Martian atmosphere would be to protect the planet against loss of heat and raise the temperature at its surface in the same way as the glass of a hot-house does. It has been calculated that an atmosphere of carbonic acid of a pressure of 30 mm. mercury, would be sufficient to raise the temperature above that prevailing on the earth. Such an atmosphere would make the temperature more equal all over the globe than is the case on the earth. Wind velocity would be smaller, water vapour might be present, and yet little formation of clouds would ensue. The white caps might in that case very well be snow.

Even the small quantity of carbonic acid which is contained in our atmosphere is generally considered to be the main factor in protecting the earth from loss of heat. An increase or decrease in its amount would change our climates greatly. Were the proportion of carbonic acid lowered from one in three thousand to one in six thousand, the mean temperature of our globe would be reduced by 5 degrees, while an increase to one in a thousand would raise the temperature by 8 degrees. Authorities believe that such a change in the amount of carbonic acid in our atmosphere might very well have occurred in the history of the earth and that the cold and warm eras demanded by geologists, might thus be explained.

Comets and Meteors.—While the bodies of the solar system move almost in circular orbits the comets follow a path which is almost parabolic. They appear from time to time in the heavens, remain visible for some weeks or months, and then fade away in the distance. In appearance they are quite different from stars and planets. Large comets are magnificent objects, sometimes as bright as Venus and visible by day, with a dazzling nucleus and a nebulous head accompanied by a train, which in some cases extends over a quarter of the sky. Since 200 B.C., on an average, three very large comets have appeared in each century. Before the invention of the telescope about 25 comets of less brilliancy were found in each century, as compared with one hundred in the eighteenth and three hundred in the nineteenth century. Eighty-six per cent. of all the comets move in parabolas or ellipses and hyperbolas whose eccentricity almost equals unity. These comets never return; they are mere visitors to the solar system. The remaining 14 per cent. have elliptic orbits, which as a rule are so elongated that the comet will not reappear for centuries. There

are, however, 18 comets known, against 2 a hundred years ago, which have at least once returned. Their periodic times lie between three and seventy-six years.

Five short periodic comets and about twenty-five more whose return has not been observed pass very near the orbit of Jupiter, and at one time they must have come very near to this the largest planet of the solar system. They are called the Jupiter family of comets. The theory is now generally accepted that these comets entered the solar system centuries ago in parabolic orbits, but passing near the planet they were retarded in their motion, with the effect that the orbits became elliptical. They were, so to say captured by Jupiter for the solar system. These comets will continue to move in their elliptical orbits round the sun, until in course of time there is another approach to Jupiter. The attraction of the planet may either retard a comet, which would shorten still more the period, or accelerate it, and possibly throw it out of the solar system in a parabolic or hyperbolic orbit. Other planets have also captured comets; Saturn is credited with eight, Uranus with five, and Neptune with six. Several comets pass the average plane of the solar system at twice the distance of Neptune from the sun and suggest the existence of an extra-Neptunian planet at this distance.

Several close approaches of large comets to planets have taken place but there is no case known where they have influenced in the slightest degree the motion of the planets and satellites. From this fact it is calculated that even the largest known comet cannot have a mass which reaches one hundred thousandth of the mass of the earth. If this mass were all combined in the head, the most luminous part of the comet, the mean density of the head would be only one six thousandth part of the air at the earth's surface, that is to say, if the comets head were gaseous, the gas would have a degree of rarefaction which is only produced by the best air pumps, while if it consisted of solid matter, the particles would be far apart compared with their size. This is borne out by the fact that faint stars shine as brightly through the head of the comet as outside.

The phenomena that accompany a comet's approach to the sun have been thus described. "At the time of the discovery the comet is usually a round nebulosity, and as it approaches the sun it brightens rapidly, and a well-defined star-like nucleus develops near its centre. Then, in the case of brilliant comets the nucleus

appears to eject luminous jets and to throw off luminous envelopes like hollow shells which follow one another at intervals of a few hours and grow fainter until they are lost in the general nebulosity of the head." A tail is gradually formed increasing in size until the comet recedes from the sun. It starts at the outer shell which envelops the head towards the sun, is always directed away from the sun and more or less curved, and it is not uncommon that there are two or more distinct tails. One gains the impression that the tail is formed of material first projected towards the sun from the nucleus and then repelled by the sun. It has been proved that for the same tail the repelling force is inversely proportional to the square of the distance from the sun, each particle of the tail moving in its own hyperbolic orbit round the sun without being influenced by the other.

The comet shines principally by its own light, emitted by incandescent hydrocarbons, but also it reflects some sunlight. On close approach to the sun the hydrocarbon radiation grows relatively faint, and luminous sodium preponderates, and in one case where the comet almost grazed the surface of the sun the principal radiation came from luminous iron gases. As to the cause of luminosity, it is certain that it cannot be caused by mere heating of the mass of the comet except in the singular case where the comet almost touched the solar atmosphere; because, the temperature would be two low. When the comet is as far away from the sun as the earth, it already shines brightly though its temperature cannot exceed 150 degrees Centigrade, which is, of course, quite insufficient to make hydrocarbons incandescent. The theory now adopted attributes the light to electric discharges. It is supposed that the central portion of the head of a comet consists of small detached solid bodies, meteorites, on which hydrocarbons, sodium and other substances are condensed in the liquid or solid state. The solar heat evaporates the volatile hydrocarbons and the sodium. They are ejected from that part where the heat is greatest, that is, the side facing the sun. These gases meet the negatively charged particles of solar origin which I have mentioned in connection with the Corona and the Aurora. The gases condense on these particles and according to their diameter they either fall back towards the meteorities, float in the hydrocarbon atmosphere at a certain distance from the nucleus, or are repulsed by the pressure of sunlight, moving in hyperbolic orbits away from the sun. The two first form the head the latter the

tail. The luminosity is caused in the same way as the Aurora Borealis. The theory is supported by the fact that every time the earth has passed through the tail of a comet there has been a brilliant display of Auroras.

There are several instances in which a number of comets follow one another in the same orbit. The most remarkable group is composed of the great comets of 1668, 1843, 1882, and 1887. It is considered certain that they have a common origin. The theory is generally favoured that they are the result of the disruption of a single comet and it is supported by the fact that such a disruption has actually once occurred under the eyes of the observers. There are several causes which favour disruption. The effect of the attraction of a planet or of a star is not the same for all the particles which constitute the large nucleus of the head of the comet. The individual small bodies will be differently accelerated or retarded in their motion, and thus their orbits and motions differently changed. What will take place will depend on the mutual attraction of meteors or their size and mutual distance and their grouping. The comets might cluster round two or more centres, in which case there would be several comets moving continually further apart; in other cases there would be increased scattering of the particles or meteorities. The larger meteors of such a cluster are further liable to be broken up. When they approach the sun they become intensely heated by the radiation of the sun, and molecular forces are set up which may burst the body and throw the fragments into different orbits. Owing to this tendency to disruption, comets must disintegrate in the course of time. That swarms of meteors actually move in the orbits of comets is an observational fact which was brought to light in the latter half of the century. The most notable of the periodic swarms are the August meteors, the November meteors, and the Andromedes, which move respectively in the orbits of the comets discovered by Tuttle, Temple, and Biela. The extent of the densest portion of such swarms is to be measured by hundreds of millions of miles and the diameter of the swarm exceeds half-a-million of miles. The individual bodies are, however, far apart and very small. For instance it is estimated that the particles composing the November meteorites weigh less than an ounce each and are from fifty to a hundred miles apart. Considering the minuteness of their size and their great mutual distance it cannot astonish us that the sunlight reflected by a swarm has never been perceived.

In fact, they only become visible when the earth passes through a swarm.

A meteor becomes heated when it passes through the atmosphere and gets in consequence continually retarded in its motion. The effect is the same as if the meteor were stationary and the molecules of the gases of the atmosphere moved against it with a speed increased by that of the meteor. In accordance with the kinetic theory of gases the gases become greatly heated. For a velocity of the meteor of only twenty miles per second the heat of the gases is about that of a blow-pipe flame, and the effect on the meteor is the same as if such a flame were playing on its front surface. The meteor thus becomes highly luminous, matter at the front is fused or liquified, and a portion of it is swept off by the air and condenses as it cools into a luminous tail. This continues until the meteorite is consumed, or until its velocity is reduced to a mile per second when the surface solidifies. Should the meteor reach the earth, the velocity is only a few hundred feet per second. As the meteor is heated only during a few seconds, there is no time for the heat to be conducted deep into the interior. In fact, meteors have been found in damp soil soon after they fell, coated with ice. The meteorites which constitute a swarm seldom weigh more than a quarter of an ounce, and they are consumed already in the upper layers of the atmosphere.

In addition to these periodic showers enormous numbers of meteorites daily enter our atmosphere; ten to twenty millions are estimated to be visible to the naked eye and a hundred millions in a telescope. To judge from their velocity most of them come from interstellar space and we are therefore led to the conclusion that the whole solar system contains them in great numbers. We can form an idea of their distribution near the path of the earth from the number actually counted. Small bodies weighing from a few grains to an ounce are moving in all directions at cosmical velocities, and are on an average about one hundred and fifty miles apart. Larger bodies of the mass of a pound or more, are two hundred times as far apart, which is five diameters of the earth, and it is this class from which the fragments collected in our museums come. Most of the fragments which have been analysed are stones containing particles of iron, and they are composed of minerals resembling minerals of volcanic origin. Only a few are pure iron. It is remarkable that no new chemical element has been found in them. On account of their high

velocity it is improbable that ages ago they were ejected by the planets or moon. I have already mentioned that a number of them are the result of the disintegrations of comets, others are supposed to be agglomerations which are gradually formed by collisions of the microscopic particles which are driven by the pressure of light-rays away from the sun and stars.

THE STELLAR UNIVERSE.

From ancient times until the beginning of the eighteenth century the study of the motions of the planets absorbed almost exclusively the attention of astronomers. The stellar universe appeared motionless and seemed to offer no problems. Positions of stars were observed from time to time mainly as points of reference for the positions of the planets. Only a few astronomers concerned themselves with star places, and the works of only half-a-dozen from 200 B.C. to the middle of the eighteenth century have come down to us. About the beginning of the eighteenth century the fact was brought out that a few of the brighter stars had appreciably altered their position in the heavens since the beginning of the Christian Era, but the changes of position per year were found so small that, considering the accuracy of the observations, ages appeared to be necessary for their determination. Yet, there were some far-sighted men who devoted their energy to the improvement of astronomical intruments and refinement of observations, and succeeded in securing observations of star places which almost rival in accuracy those of the present day. In 1760 it was an established fact that the stars move more or less, and apparently indiscriminately in all directions. The year may be said to mark the beginning of Stellar Astromony. The few observatories then in existence were rivals in the determination of accurate star places, with the result, that a hundred years ago the number of stars which had been observed had risen from a few hundreds to twenty thousand. The first fruit of the labours of the astronomers of the first half of the eighteenth century was the discovery that the whole solar system moved in space in a certain direction. Stars in the apex of motion of the solar system behaved as if they were moving indiscriminately in all directions, while those at right angles showed in their motion a preference for the direction which lies opposite to the apex. The problem of the determination of the position of the apex rests on the hypothesis that

all kinds of motion are equally probable in all parts of the heavens. Early in the century it was recognised that such an assumption can be true only for a great number of stars. Consequently observation of the position of stars was taken up more vigorously than before; instruments were improved, and the methods of correcting the star places to the same planes of reference were brought to a high degree of refinement. There is hardly an observatory of any standing which has not participated in this immense work, and it may be safely stated that the majority of astronomers of the past century has been engaged in it. At the present day we possess catalogued positions of great accuracy for upwards of 200,000 stars, all derived from direct measurements on the heavens, and their accuracy is greater than that of the positions of the few fundamental stars employed one hundred years ago. On the completion of this work photography was resorted to, to extend it still further. For the last fifteen years a photographic survey of the heavens has been in progress and approaches completion. Based on the survey made by the eye it will furnish us with the positions of two million stars, the faintest having only one hundredth of the brightness of the faintest visible to the naked eye, and it will provide us with a chart of all the stars which are visible in the largest telescopes. What the number of these stars will be can not even be guessed.

The ultimate object of Stellar Astronomy is the solution of the problem of the structure and duration of the Stellar Universe. During the past century a beginning has been made in providing the facts on which the solution must be based. They comprise positions of stars in the heavens, their motions in the heavens and in the direction of vision, their distances, photometric brightnesses, and spectra. Though the observational data are principally a bequest to future times, they suffice to give us at least a vague idea of the space occupied by the stellar universe. Were it possible to measure the distance of each individual star, distance and direction would enable us to make a model of the stellar universe. The problem before us then is equivalent with the dermination of the distances. Unfortunately, direct measurement of the distance is confined to the few stars nearest to us. The principle involved is this. Owing to the earth's motion round the sun, we are able to look at a star from different standpoints in the course of a year. The effect is the same as if the earth were stationary, and the star described an orbit of the

same linear dimensions as that of the earth. The apparent dimensions of this yearly orbit of the star can be obtained from observations distributed all over a year. The work is laborious, and it might be mentioned that only the delicate apparatus introduced in the course of the past century made the feat possible. Attempts at such a determination date three hundred years back, when the probable error of the measurements was a hundred times as great as the angle to be discovered. Indeed, Tycho Brahe rejected the Copernican theory on the ground that stars did not reflect the earth's motion. At present we know the distances of seventy-two stars, which were selected for the determination of distance either on account of their brightness or their large motion. The nearest star is about 300,000 times as far away from us as the sun, or, in a more convenient unit of length, four-and a-half *light-years;* a light-year being the distance that the light travels in a year. Thirty-nine stars have been found within a distance of thirty-three light-years, but it is reasoned that about eighty-eight probably exist within this range. On this assumption each star would occupy on an average a spherical space of seven light-years radius. The average distance of the nearest stars from one another would therefore be several times greater than the distance of the nearest star from us. The nearest star happens to be very bright, of the first *magnitude*, but the second in the list is invisible to the naked eye; it is remarkable that both these stars have exceptionally large *proper motions.*

The direct method for the determination of distance cannot be used for stars which are farther off than 100 light-years, because, the dimensions of the apparent yearly orbit of the star are smaller than the errors of measurement. In the case of a double star for which the elements of the relative orbit of the two components have been derived another method presents itself. The relative velocity of the two stars, and its component in any direction can be calculated in miles provided the distance of the star from us be known in miles. But the relative velocity of the stars expressed in miles can be observed from the relative displacement of the spectral lines, and therefore the distance can be found in terrestrial units of length.

For the multitude of the stars we have no method which determines their individual distances. All that can be obtained is the average distance of a group of stars. The question then arises, in what way have the stars to be classified so that the

distance ascribed to a group does not differ too much from the individual distances? If the stars were all equally large and had the same intensity per unit of area, stars of the same brightness or magnitude would be at the same distance. Though size and intensity vary greatly, it might be inferred that as a class stars of magnitude m are on an average nearer than those which appear to us of magnitude $m+1$. According to photometric measurements a star of magnitude m sends us two-and-a-half times as much light as a star of magnitude $m+1$, and as the intensity of light decreases with the square of the distance, we can calculate the distances in some arbitrary unit, on the hypothesis that at all distances size and intensity are on an average equal, and on the supposition that light suffers no absorption in interstellar space. The hypothesis is susceptible to test. It is an observational fact that equal areas of the sky in any two opposite directions contain almost the same number of stars. Unless we make some improbable assumption as a unique position of the solar system in the stellar universe, we must conclude that *in all directions equal volumes of space contain equal numbers of stars.* Such being the case the relative number of stars contained in spheres of different radii may be calculated, and thus the relative number of stars of each magnitude may be obtained and compared with those actually counted. The agreement of these numbers is, though not unsatisfactory, hardly conclusive.

In another attempt to obtain the relative distances of stars of different magnitude, the reverse course was chosen, the observed numbers of stars and the probable hypothesis of equal density of stars in space being introduced instead of the hypothesis that size and intrinsic intensity of stars were equal at all distances. In this investigation the remarkable result was obtained, that for stars visible to the naked eye, (first six grades of the magnitude scale), the radius of the sphere which encloses all the stars of magnitude $m+1$ is [illegible] times as great as that of the sphere which encloses all the stars of magnitude m. The result is still accepted. In this way we learn nothing about the average distances of stars of a certain magnitude, because neither the minimum distances of the stars of each magnitude are known nor are the distances obtained in a known unit of length.

The third method utilises the proper motions of stars. The real motion of [illegible] stars is supposed to take place in a straight line with uniform velocity, and [illegible] the direction of the motion cannot

possibly have any relation to the direction from earth to star, it may make any angle with that direction. The component of the real motion which lies in that direction, the motion in the line of sight, does not admit of being determined by telescopic vision, but can be found in terrestrial units of length from the displacement of spectral lines provided the star is bright enough. The component in a plane at right angles to the line of sight subtends an angle at the earth, and it is this angle which is called the *proper motion.* Now, let the solar system move towards a point of the heavens, which as we know lies in the constellation *Lyra*, then we can resolve the observed proper motion into two components, one in the direction towards the apex of the solar system, the other at right angles to it. The component which lies in the direction of the apex reflects the solar motion. Stars which actually do not move in that direction appear to us to move towards the anti-apex at the same angular rate at which the solar system appears to move towards the apex as seen from the star. The apex-component of any other proper motion is affected in the same way. Let us correct the apex-component or each observed proper motion for the motion of the sun, then, if we choose a great number of stars the average apex-component calculated with regard to sign and the average component at right angles to it also calculated with regard to sign should come out zero, because all directions of the real motion are equally probable. Conversely if we do not know the position of the apex and the angular velocity at which the solar system appears to move as seen from a star at a certain distance, we can determine these unknowns from the observed proper motions of stars which are equally far away from us. In a tentative way it was supposed that stars of the same proper motion have an average distance from us which is greater than the average distance of stars showing a greater proper motion, and groups of stars were formed according to the amount of proper motion. From the group of small proper motion a small angular motion of the solar system results, and in proportion as the average proper motion in a group of stars is larger, this angular solar motion also increases, while the position of the apex of motion comes out practically the same in all groups. The several groups contain stars of all magnitudes of brightness, but their average brightness is the same for all groups. On an average, stars of small proper motion must therefore be farther away from

us than stars of large proper motion, and the distance increases in the ratio in which the average proper motion decreases. This then proves that the apparent proper motions of the stars give an indication of the distances of stars from us, and further, that the average linear velocity of the stars without regard to direction is the same at all distances.

The second step towards the knowledge of the distance of a group of stars of the same proper motion is to determine the linear velocity in some known unit. In the spectroscope we can measure the displacement of lines and calculate the relative velocity, expressed in miles, of the star and the earth in the line joining them. The observations are still too few to determine the average value of this component, which on the assumption of equal probability for all directions stands in a fixed proportion to the desired quantity; they suffice, however, to give a trustworthy value of the linear velocity of the solar system towards its apex. The average velocity with regard to sign of stars which lie in the direction of the apex and opposite, is not zero as should happen if the sun were stationary in space, but 12 miles per second, or 4 radii of the earth's orbit per year, which quantity must be ascribed to the motion of the solar system towards its apex. By a statistical method we can compare the sun's motion with those of the stars in a plane at right angles to the line of sight. According to countings of the proper motions of stars which are towards the apex and away from it, 23 per cent. of the stars are moving towards the apex, against 77 per cent. from the apex. While the former move faster in the direction of the apex than the sun, the latter 77 per cent. is composed of stars which actually move towards the anti-apex, and of those which move towards the apex at a slower speed than the sun and are overtaken by the sun. On the adopted hypothesis that all directions of motion are equally probable there will be equal numbers of stars moving in two opposite directions at a speed which exceeds any arbitrary quantity. Thence twice 23 per cent. or 46 per cent. of the stars move faster, and therefore 54 per cent. slower than the sun, which entails that the average component of the stars' linear velocity in the direction of the apex or anti-apex, equals about the velocity of the sun, or 3·7 radii of the earth's orbit in a year. The other two components have the same average value, and the resultant velocity in a plane at right angles to the line of sight becomes 6 radii of the earth's orbit per year. This quantity

will subtend at the earth an angle of one second, viz., the proper motion is one second per year if it be placed at a distance of twenty light-years. It is estimated that there are about 80 stars which have a proper motion equal to or greater than one second. These 80 stars lie in a sphere of 20 light-years radius, as compared with our former estimate of 82 stars occupying a sphere of 33 light-years radius. The indirect method just explained is applicable only for a group containing a great number of stars, and for this reason alone the latter estimate ought to be preferred.

In the same way the average distance of any group of stars may be determined from a statistical study of the proper motions. Calculations have been carried out for stars of each class of brightness and for blue stars and yellow stars separately. For physical reasons blue stars are hotter and more luminous per unit area than yellow stars, and they are also much larger for the same mass, hence, a blue star must stand much farther away from us than a yellow star of the same mass to appear as bright as the latter. This agrees with the result obtained from the proper motions which places the blue stars on an average two-and-a-half times as far off as yellow stars of the same apparent brightness. The faintest stars visible to the naked eye are on a average at a distance of 180 light-years for yellow stars, and 400 light-years for blue stars. What the range of distance is for each magnitude cannot be ascertained.

The proper motions of the naked-eye or lucid stars have also been discussed irrespective of magnitude. For one half of their number the component of the proper motion at right angles to the apex direction is less than the 2·5 seconds per century to which a distance of 500 light-years belongs, while one sixth of their number must be placed at not less than 1,300 light-years. Interesting results will be obtained when the proper motions of the fainter stars become available; all we can say at present is that the sphere of lucid stars extends much beyond 1,300 light-years.

I have already alluded to the fact that the number of stars in any two opposite directions from us are almost equal, and we have inferred from the equality that out to a great distance stars are scattered without much deviation from uniformity. On the assumption that each star occupies on an average as much space as found from the direct determination of the distances of the nearest stars, the sphere which encloses most naked-eye stars—

about ten thousand—would contain ten million stars. As the number of the telescopic stars brighter than the tenth magnitude is below a million, the faintest telescopic stars must extend far into the region of the lucid stars, and the majority of the stars must therefore either be smaller or less luminous than the lucid stars.

Were the number of stars, visible and invisible, known, we might get an idea of the space occupied by the stellar universe. On the star-charts we can count the number of stars of each magnitude and calculate the ratio of the numbers respectively belonging to successive magnitudes. This ratio of the numbers of stars does not differ much for the first nine magnitudes, and for these magnitudes is 3·25 near the pole of the Milky-Way, and 3·85 in the zone embracing the Milky-Way. For example, there are 3·25 times as many stars of the fifth magnitude near the pole as there are stars of the fourth magnitude, and again 3·25 times as many of the sixth as there are of the fifth, and so on. Now by the definition of the magnitude-scale a star of the fourth magnitude sends us 2·5 times as much light as a star of the fifth magnitude, and this ratio is constant for successive magnitudes. Hence all the stars of the fifth magnitude send us 3·25 divided by 2·5 or 1·4 times as much light as all the stars of the fourth magnitude. On the assumption that the ratio of the numbers of stars of two successive magnitudes is a constant quantity (3·25 or 3·85) no matter how faint the stars are, all the stars of a certain magnitude would send us 1·4 times as much light as all the stars which are a magnitude brighter, with the result that the whole sky would shine with a blaze of light like the sun. In reality the total star-light is only about 1,000 times that from a star of the first magnitude or a two-hundredth of the light of the full moon, and we must therefore conclude that at some point of the magnitude-scale the ratio under consideration must fall off, or in other words, that stars are far less numerous in the distant regions of space than in the region occupied by the visible stars. From all the data available it is supposed that the number of stars, visible and invisible, cannot exceed 100 millions, and that, apart from the Milky-Way, stars do not extend far beyond a sphere of 3,000 light-years' radius.

Up to this point the hypothesis has been adopted that stars occupy on an average equal space in all directions, because, there is an equal number of stars in any two opposite directions. A

mere inspection of the sky shows us that there are many more stars round the belt of the Milky-Way than at right angles to it. To reconcile this fact with the hypothesis it was assumed almost a century ago that our stellar universe is composed of a comparatively thin but widely extended stratum of stars, its figure resembling that of a large thin grindstone, the principal plane of which coincides with the plane of the Milky-Way and contains the solar system. This assumption was based on the actual number of stars, irrespective of their magnitude, which were visible in the field of a powerful telescope and counted in a great many parts of the sky. According to these countings the number of stars in any part of the sky simply depends on its angular distance from the plane of the Milky-Way, and gradually and systematically decreases from the Milky-Way towards its poles. For equal areas of the sky there were found twenty stars near the Milky-Way for every one that stands at right angles to it.

When in the course of the century accurate catalogues and charts of stars up to the 9·5 magnitude became available, these countings were repeated with reference to magnitude. The most striking result of these studies is, that *the condensation towards the Milky-Way begins with the brightest stars.* We might explain this by imagining the nearest stars to become gradually more numerous towards the plane of the Milky-Way, but this demands the solar system to be placed in a unique position, an arrangement which must be dismissed as outside all reasonable probability. On the other hand, the thickness of the disk cannot exceed much the average distance of the class of stars which increase in numbers towards the Milky-Way. It follows that the brightest stars which show the condensation must be situated at distances which exceed the distance of the nearest boundary of the stellar disk. The tendency of the stars visible to the naked eye to cluster round the Milky-Way has been demonstrated in a simple way. When only these stars are entered on a sphere the course of the Milky-Way is clearly traced out by their crowding in that region.

The distribution of the 135,000 stars up to magnitude 9·0 is similar, they, too, decrease in numbers from the Milky-Way towards its poles, but the ratio of the numbers for equal areas in the Milky-Way and its poles is three to one, as compared with twenty to one for all the stars visible in a large telescope. The gradual decrease from the Milky-Way to its poles cannot be ex-

plained by a ring of stars surrounding a spherical system of stars, and the conclusion must be drawn, that the Milky-Way is connected with our stellar system.

If the space occupied by the stars be flattened the farthest stars should be most crowded towards the Milky-Way, and the nearest stars, *i.e.*, those with large proper motions should be equally numerous in all directions. Both consequences are borne out by observation. As a class faint stars are farther than bright stars, and we have seen that the ratio expressing the crowding is greatest for the former; for the same apparent magnitude blue stars are more distant than yellow stars, and there is actually a greater proportion of blue stars near the Milky-Way than at its poles; on the other hand—and this is the most important argument in favour of the hypothesis—stars which move more than 5 seconds in a century are nearly equally distributed over the sky.

According to the above a distance of 400 light-years belongs to a proper motion of 5 seconds per century, and this is about the minimum distance which the nearest boundary of the universe is from us. Whether it is much more cannot be decided at present, because we don't know as yet with certainty the stars which move at a slower rate.

Probably this distance is ten times as much and considerably more in the direction of the Milky-Way. The sun cannot stand far from the central plane of the Milky-Way, because the Milky-Way is very nearly a great circle on the celestial sphere.

By a statistical study of the number of stars we might also form an idea at what distance this wonderful belt has to be placed. It is obvious that the inequalities of its structure, which are visible to the naked eye, and still more pronounced on photographs, cannot be the result of a uniform stratum of stars. There must be large local aggregations of stars; and the question arises, what brightness have the stars which participate in these aggregations? Lucid stars were counted in the dark galactic regions and in the bright galactic regions, and the number per unit of area compared with the average for the sky. It was thus found that the dark areas are only slightly richer in stars than the average sky, whereas the bright regions contained almost twice as many. For faint stars the increase in numbers becomes the greater the fainter the stars. Hence we must conclude that the Milky-Way is actually bound up with our system of stars and reaches within the region of the lucid stars.

The stellar universe then forms one stellar system, the galactic system. Within this system stars group together and form sub-systems recognisable by their common proper motion. Here and there we meet clusters so closely arranged that the mere inspection of them impresses us with the idea that the stars must belong together. Also, these clusters principally occur near the Milky-Way and thus emphasise their connection with the galactic system. The condensation of the stars of the stellar universe towards a plane has its parallel in some of the nebulæ. Let us take the nebula in Andromeda. Its dimensions are enormous. Even should the nebula not be farther than an average star of the first magnitude its diameter would be two thousand times that of the solar system. Light would require two years to travel from one end to the other. Most probably the distance of the nebula is many times as great and its dimensions comparable to the distances of faint stars from us. Its appearance is the same as if the nebula were a circular disk, whose principal plane is inclined to the line of sight. In the faint outlying portions a spiral structure is brought out, a feature which is not uncommon in this class of nebulæ to judge from photographs recently secured. It has been suggested that the Milky-Way may be similarly constituted and that the apparent bifurcation of the Milky-Way might be due to the solar system standing somewhat outside the principal plane of the spiral. The spectrum of the nebula is exceedingly faint, and all attempts to register it on the photographic plate may be considered as failures. The little evidence we possess from eye observations points to a continuous spectrum. In that case it is an immense star cluster in which the faint stars stand so close that they cannot be separated from one another.

At the end of the eighteenth century most of the clusters and nebulæ were discovered and catalogued, but with no pretence to great precision. In the nineteenth much observational material has accumulated, photographic and micrometric, which in future times will be valuable in determining changes and motion. One of the first discoveries made with the spectroscope was to disclose that there are two distinct classes of nebulæ; the stellar, to which the nebula in Andromeda belongs, and the gaseous nebulæ of which the nebula in Orion is the largest representative. In the case of gaseous nebulæ the total light is not scattered over the whole spectrum as for the stellar nebulæ, but is distributed only over a few lines, with the result that the

spectrum is readily seen or photographed. These nebulæ send us light from the same gases Hydrogen, Helium, and the unknown gas Nebulum, and no matter at what part of the heavens a gaseous nebula stands its spectrum is a repetition of what is seen in other regions. The gaseous nebulæ are now considered to belong to our stellar system, though they do not share with stars and clusters the systematic increase in numbers towards the Milky-Way. As a rule they abound where there are no stars, just as if the stars were the cause of their absence, or as if the stars had consumed or attracted the nebulous gases. This fact has been utilised in modern theories on the evolution of stars. Direct evidence is not wanting that the gaseous nebulæ are to be placed within the space occupied by the stellar system. In the large nebula of Orion bright stars are enveloped which show some of the characteristic lines of the nebulæ and suggest a genetic connection with the nebula. In the Pleiades the connection of stars and nebula is brought out still more strikingly, showing as it does a distinct condensation of the nebulous mass towards these stars. Until quite recently we had no plausible explanation to offer for the luminosity of the nebulæ. The light we see comes from luminous gases, and to judge from the breadth of the spectral lines the density of the gases must be small. Were the luminosity due to the heating of the gases, one should expect a globular mass to appear more luminous near the centre than at the edges, which is contrary to the appearance of the round equally illuminated planetary nebulæ. Again, if the gases were hot we should have to assume an attractive force strong enough to retain the molecules of the gases, as otherwise in course of time they should have dissipated into space; but this entails that the density of the gases should increase inwards and the spectral lines be broadened, which is contrary to our experience. On the other hand, if the gases be cold it is difficult to account for the luminosity except by electric discharges. Perhaps here, too, as in the case of comets and auroras we meet again the action of the negative electric particles, which thrown out and repulsed by sun and stars are caught by the nebulous mass. The theory has certainly this in its favour that it explains why the nebula shines with the light of the volatile gases which are most likely to constitute the surface layers of an agglomeration of all kinds of substances. The only hope we have at present of disclosing their nature lies in the discovery and study of the so-called temporary stars.

When in the middle of the eighteenth century it became an established truth that stars are not so far away as to conceal their motion from us, one began to consider it possible that an orbital motion of stars might be found. Attention was especially drawn to the number of stars standing close together, whose proximity was until then considered merely an effect of projection. From the theory of probabilities it was proved to be highly improbable that there should be so many instances of two stars standing in the same direction. Astronomers began to search for double stars and fix their relative positions, with the result, that in the year 1803 changes in the relative position of a number of stars could be traced. Since then double stars have been the object of numerous researches, observational and theoretical. At present there are about 12,000 double stars known, of which ten per cent. have shown signs of revolution. Of stars brighter than the ninth magnitude about five per cent. are probably composed of two suns visible in the great telescopes. Obviously only systems near to us will reveal their duplicity in the telescope, and if this be taken into account it is estimated that two stars out of three are double or multiple systems.

There are only sixty-six systems, the orbits of which have been calculated, thirty-eight having periods of revolution less than one hundred years, with a minimum of six years. The observed motions all satisfy Newton's Law of Gravitation, but owing to unavoidable errors of observation it has as yet been impossible to decide whether or not the law is rigorously true in those distant spaces. A prolonged study of the motion of the most eccentric systems will eventually give a precise criterion for the rigour of this law the absolute universality of which can at present only be regarded as probable.

We know the distances from the sun of only a few double stars and in their case the dimensions of the orbit and the constant of attraction can be expressed in terrestrial units of length. None of the orbits cover so large an area as is occupied by the solar system, and the combined masses of the two stars range from a third to three times the mass of the sun.

In the case of the bright star *Sirius* the orbital motion was found from the periodic change of place with reference to neighbouring stars, and it was a decade later when the dark mass which caused this motion was recognised as a small star of only one ten thousandth the brightness of *Sirius* though its mass was calculated to amount to a quarter of the mass of *Sirius*.

Since then the spectroscope has revealed to us numerous binary systems of which one component sends us no appreciable light.

I have explained that the displacement of spectral lines gives us the rate of motion expressed in miles. In the case of a binary star which moves round a dark mass in a plane not at right angles to the line of sight, the star moves periodically towards us and away from us, and consequently the spectral lines oscillate round their normal positions. The variable star *Algol* is a case in point. Already in the seventeenth century the star was known to be variable in brightness, but more than a hundred years passed before the regular character of the changes of brightness was recognised. This star is generally of about the second magnitude, then in about four hours it gradually decreases to one-fourth of its brightness, remains faint for a quarter of an hour, after which it regains its greatest brightness in four hours as before. The phenomenon repeats itself every three days, the period being known to a fraction of a second. The correct explanation was put forth immediately, namely, that it is a stellar eclipse, a dark star moving in an orbit round the bright *Algol* and partially obscuring it at regular intervals. The spectroscope has established the hypothesis as a fact. Seventeen hours before the minimum *Algol* recedes from us at a rate of twenty-seven miles per second, and seventeen hours after the minimum it moves at almost the same rate towards us. Now, the ratio of the brightnesses of the star at maximum and minimum gives us the ratio of the diameters of the two bodies, and the duration of the minimum, which is the time the dark star appears inside the disk of the bright star, combined with the known velocity in miles, determines the difference of the diameters in miles. The periodic time and the diameter of the orbit in miles gives the constant of attraction and hereby their combined masses as compared with the sun. The dark star is almost exactly the size of the sun, the bright star is slightly bigger, and their mutual distance is less than four times their diameter. Both together have only two thirds of the mass of the sun, and their density is only a quarter of that of water. The calculation rests on the assumption that the orbit is circular, and that the two bodies are equally dense.

There are known 17 variables or binaries of the *Algol* class whose light-variations have been exactly determined. Incomparably more systems must occur for which the plane of the orbit of dark and bright stars does not pass through the line of sight and

which cannot manifest themselves by light-changes. These systems can only be discovered from the periodic changes of the velocities in the line of sight and they have to be carefully searched for.

In other binary systems both stars are luminous, but their apparent distance is so small that even in the most powerful telescopes they appear as one star. Take the simplest case where the star system remains at the same distance from us, and the motion is in a plane which passes through the line of sight. When one star is moving towards us in its orbital motion the other must be in that part of its orbit where it moves away from us. The one gives a spectrum in which all the lines are displaced in one direction, while those of the other star are displaced in the opposite direction. Both spectra are observed together and therefore those lines which are common to both stars, will appear double. After a quarter of the periodic time the stars are moving at right angles to the line of sight, and the spectral lines having their normal position, the lines which appeared double before, will now be single. As to the brightness, the smaller star will pass once during each revolution in front of the larger one, once behind, and there will thus be two minima of brightness and two maxima which take place when the stars do not cover each other. The minima need not be equally bright unless both stars be of the same intensity. The β *Lyrae* class of variables belongs to this spectroscopic and photometric class of binaries. In the case of β *Lyrae* the eclipses are only partial, because, both stars show their spectra at both minima. The relative velocity of the two stars constituting β *Lyrae* is 120 miles per second, and the distance of their centres is only six times the diameter of the sun, and it is considered probable that both stars are almost in contact, and their density extremely low. Some regard them as stars in the process of forming.

When the motion is not in the plane passing through the line of sight there is no change in brightness and the stars are spectroscopic binaries. So far, a dozen spectroscopic binaries of this type have been discovered. In the list there is one faint star just visible to the naked eye the components of which have a mass more than 70 times that of the sun, and move relatively to each other at the enormous velocity of almost 400 miles per second.

The spectroscopic researches of the past decade have disclosed several systems in which the distances of the two stars are only a little larger than the diameters. At such close approaches the

tide raising forces must be immense, and their form must greatly differ from a sphere. Kepler's laws of motion cannot strictly apply to their motion, and there will be large perturbations of the motion set up by the lagging of the tides. The study of these binaries will eventually throw invaluable light on the evolution of stars and on the formation of our own system.

A star will appear variable, not only by being eclipsed by another star, but by a change in its surface brilliancy. Let us consider a star like our sun to be accompanied by one moving in an eccentric elliptic orbit. Every time the stars approach each other, tides will be raised on these bodies, and to judge from the solar phenomena outbursts of prominences would ensue, and faculæ would be formed which might greatly outshine the light from the photosphere. The star would become periodically bright, and near the time of its greatest brightness the spectral lines of some of the gases might appear bright. The class of variable stars to which *Mira Ceti* belongs, exhibits the changes which I have just described. *Mira Ceti* is during most of the time invisible to the naked eye, but at intervals of eleven months it rapidly increases to the third or second magnitude at which it remains for about a week. It is remarkable that most of the stars of this numerous class are reddish in colour, and their spectrum indicates a lower temperature of the photosphere than for the sun, but these are just the stars which would show the contrast between the state of intense activity and comparative rest more prominently than hotter stars, and therefore would be the first to draw attention.

More than 600 variable stars of all types have hitherto been discovered. The number is yearly increasing—especially since photography has aided in the search for them. For more than a decade a continuous photographic record of the heavens has been taken and stored at the Cambridge Observatory in the United States, which on the discovery of a variable tells us the history of the star during that period.

While the light-changes of variable stars are periodical, temporary, or new stars, suddenly appear, and then steadily decrease in brightness. Until about fifty years ago only four such stars had been noticed, as compared with eleven in recent years. The light-changes have in some cases been enormous. The new star in *Perseus*, which appeared in 1901, has been the brightest for 300 years, and was for a few hours the brightest

star in the heavens, though two days previously it was too faint to be registered on a photographic plate which registered stars of the twelfth magnitude. We thus know its history perhaps from a few hours after its outburst. Its brightness gradually decreased; by the end of six months it was invisible to the naked eye, and after another six months it had dwindled to a faint telescopic star. Two days after the discovery the star shone in the light of a solid surrounded by a gaseous atmosphere, and again, after the lapse of another two days the radiation was almost entirely due to luminous Hydrogen and Helium, whose spectral lines were, immensely and systematically broadened. Then after four months new radiations came into existence, the characteristic radiations of a gaseous nebula, and they more and more predominated. Before a year had passed the star, or what appeared from us to stand at the same place, had become a nebula. An identical course was followed by the new star in 1892. The explanation most favoured at present is that an invisible star entered a nebula at a small velocity, and that by its collisons with the solid and gaseous masses of the nebula, the dormant energy of the star was brought into play. This would account for the outburst and the spectral changes on the days immediately following. As yet we do not possess a satisfactory explanation of the broadening of the lines and the series of reversals within these lines, nor for the sudden appearance after four months of the nebular lines and also their immense broadening. That there is a nebula, gaseous or stellar, concerned in the phenomenon is known from other evidence. Six months after the outburst of the new star in Perseus a faint nebulous ring was photographed which surrounded the star at a distance of about a quarter of the diameter of the moon, and as time went on this ring widened out at a velocity which, considering the enormous distance of the star of more than a hundred light-years, must have been of the order of the velocity of light. It is believed that the light of the expanding nebulous ring is the light sent out by the star on the day of its outburst, and reflected towards us by solid or gaseous matter which surrounds the star to a distance of at least a light-year.

The physical side of Stellar Astronomy was only three years ago brought before the Society by Professor Schuster in a lecture on "The Evolution of Solar Stars,"[1] and it is therefore unnecessary for me to include it in this address.

[1] *Proceedings*, vol. xxxiii.

A Thirteenth Century Tomb in Glasgow Cathedral.

By P. MACGREGOR CHALMERS, I.A., F.S.A.(Scot.).

[Read before the Historical and Philological Section, 1st March, 1905.]

THE presence of the shrine of S. Kentigern in the lower church or crypt of Glasgow Cathedral probably secured for this part of the sacred building a large measure of the interest of mediæval times. Nor is our interest less to-day. The crypt is admitted to be one of the finest creations of the mediæval architect in Scotland. It is beautifully proportioned and is so richly decorated as to convince us that it was designed not to remain in a state of gloom but to be a well-lighted place of worship, the acoustic properties of which are perfect, both for speaking and singing, as the services now annually held there have proved.

To the student of Scots mediæval architecture and to the antiquary the crypt has an additional interest since it contains the solution of several problems connected with the growth and development of the whole building. The unique disposition of the pillars in the centre aisle has frequently attracted attention, and there can be little doubt that this feature in the design gives great charm to the interior. But it is not wise to suppose that the arrangement of the pillars was an arbitrary or entirely fanciful one, or that it was a departure from the original design. The suggestion is offered that the architect arranged the pillars in the centre aisle in order to distinguish two sacred sites —the original site of the altar and tomb of S. Kentigern near the west end, and the site of the chapel of the Blessed Virgin Mary under the high altar of the great choir at the east end.

Recent investigation proved that there still remains a considerable part of the north wall of the north aisle of the choir restored by Bishop Jocelyn after the building was destroyed by fire, and dedicated by him in the year 1197. This fragment is of the same extent, measuring from east to west, as the late twelfth century aisle on the south side which has incorporated in its eastern wall a portion of an earlier building. These fragments of buildings on the north and south indicate the limits of the choir aisles of the late twelfth century foundation. Although all trace of the centre aisle has been removed from above the floor level, the

evidence of contemporary choirs justifies the opinion that the centre aisle was terminated in a semi-circular apse, and doubtless this apse enclosed the site now marked by the four slender columns grouped in a square which was, in the 13th century, the site of S. Kentigern's shrine.

As S. Kentigern's altar and grave were well known at the beginning of the twelfth century, when prince David refounded the Cathedral, we can hardly believe it possible that he did not follow the mediæval custom and erect the altar of his new cathedral over this sacred spot.

For many years the writer entertained the desire to examine the foundation of the present building to ascertain if perchance any part of the masonry of the twelfth century apse, or, it might be, any fragment of work of S. Kentigern's period was still in existence. A way was opened up for one part of the investigation when I was brought professionally into contact with the late Marquis of Lothian. He readily granted me permission to carry out researches at the east end of Jedburgh Abbey, which was in the diocese of Glasgow, and in many points bears a striking resemblance to the parent cathedral. The centre aisle of the choir where it extends beyond the north and south aisles is marked by a complete change in the style of architecture—the round-arched Norman giving place to the pointed transitional style. It is evident that the original east end was removed for the purpose of enlarging the building, and it was surmised that the former termination was a semi-circular apse and not the square end as at present. The investigation was carried out on the 13th January, 1898, in the presence of Mr. John Caverhill and the Revds. R. S. Kirkpatrick, and C. J. M. Middleton. It was ascertained that the greater part of the foundations of the apse had been removed, but the stones in the foundation where the semi-circular apse began were *in situ* projecting 2ft. 8in. from the face of the straight wall. The normal projection of the foundation is 1ft. 6in. The proof that there had been a semi-circular apse though somewhat limited was sufficient.

The opportunity for carrying out the cherished scheme of investigation at Glasgow Cathedral came when, through the kind interest of the Right Hon. Sir Herbert Maxwell, Bart, M.P., and Mr W. W. Robertson, H.M. Commissioner of Works for Scotland, I was able to apply directly to the Right Hon. A. Akers Douglas, M.P., First Commissioner of Works, who at once acceded to my request.

The investigation was carried out in the presence of the late Archbishop Eyre, the Very Rev. Principal Story, Dr. Macadam Muir, and other gentlemen. A considerable part of the flagstones was removed along the south side of the centre aisle, from the pillar marking the east-end of the twelfth century side aisle to the pillar east of the site of S. Kentigern's shrine. All hope of finding any part of the foundations of the apse was abandoned at the outset. It was discovered that the pillars upon which the great structure is reared are not built as isolated piers upon the earth, but upon a wall of ruble masonry measuring about 8 feet broad and rising to within 6 ins. or 9 ins. of the floor level. The depth of the wall was not ascertained, but there is no "scarcement" or projection within 5 feet of the floor level. Hard white sandy clay was reached at the depth of 2ft. 4ins.—at 3ft. 2ins. the clay was wet. The richly moulded base stones at the floor level are the first stones of the great pillars. Several fragments of broken red clay floor tiles were found scattered in the earth. The flagstones on the west, south, and east of S. Kentigern's shrine and the flagstones within the line of the four pillars were removed. No early stone foundations were discovered. But S. Kentigern's church may have been constructed wholly of timber. Its proportions would be of the most modest description, and its orientation may have been several degrees further north of east than was the custom at a later period.

The pillars at the shrine rest upon an independent wall formed four square, the outer surface of which is well-dressed. The inner face is exceedingly rough. The red-clay glazed flooring tile which was found at this point, at a depth of 2ft. 6ins. from the floor level has been handed over to H.M. Commissioner of Works for preservation. Hard, white, sandy clay was reached at the depth of 4ft. 1in.

The investigation was carried eastward without result until the south side of the centre pillar was reached when a stone foundation was discovered. The space within the wall which is 12ins. thick was filled with a rich brown earth of fine quality. As it was feared that this was a grave the search was abandoned.

The net result of this investigation is that we know that all the materials of the early structures have been removed; that the original floor of the Cathedral was laid with glazed tiles about $4\frac{1}{4}$in. square; and that the stone pillars are built upon great

walls, the upper surfaces of which reach to within a few inches of the present floor level.

The knowledge of the existence of these walls led at a later time to another discovery. It is evident that many of the detached fragments of stonework preserved in the chapter house are parts of one structure. The decoration is of the same character, and it was found possible when all the fragments were properly arranged and closely fitted together to determine that the site of the original structure was in the crypt, between two of the great pillars forming the main arcade. The large quarter round hollow at each end which was left rough for mortar—and the mortar still adheres—corresponds with the curved surface of the angle shafts of these piers. When the exact length of the structure was compared with all the openings between the pillars in the crypt, it was found to be equal to the width of the openings on the north and south sides of the chapel of the Blessed Virgin Mary at the east-end. As the steps to the chapel of the Four Altars block the eastern arches, attention was directed to the western arches on the north and south sides. The presence of an interesting and unique series of carved portraits in the vaulting of the north aisle made it probable that the north arch was the true site of the structure. Further study of the stones brought to light the interesting fact that the sill stone was checked at the ends, so that it fitted over the large bead moulding of the base of the pillars. When this was ascertained, it appeared certain that if the structure was a tomb constructed over a grave, there was not sufficient space for a sarcophagus between the underside of the sill stone and the upper surface of the great wall known to extend the length of the Cathedral. As it seemed desirable to determine if any burial had taken place at this north arch, application for permission to dig was again made and granted. The excavation was carried out on the 20th June, 1901, in the presence of Mr. W. Kennedy, the local representative of H.M. Commissioner of Works, to whom I am greatly indebted in connection with this and other researches, and of my chief assistant Mr J. J. Waddell. Five of the paving stones were removed. The upper surface of the wall was reached at 6½ins. below the floor level. A small part of the original surface has been preserved at the east side, but the greater portion has been cut away lowering the level to 13½ins. below the floor. Although it was believed that the site of the tomb had been ascertained, the alternative

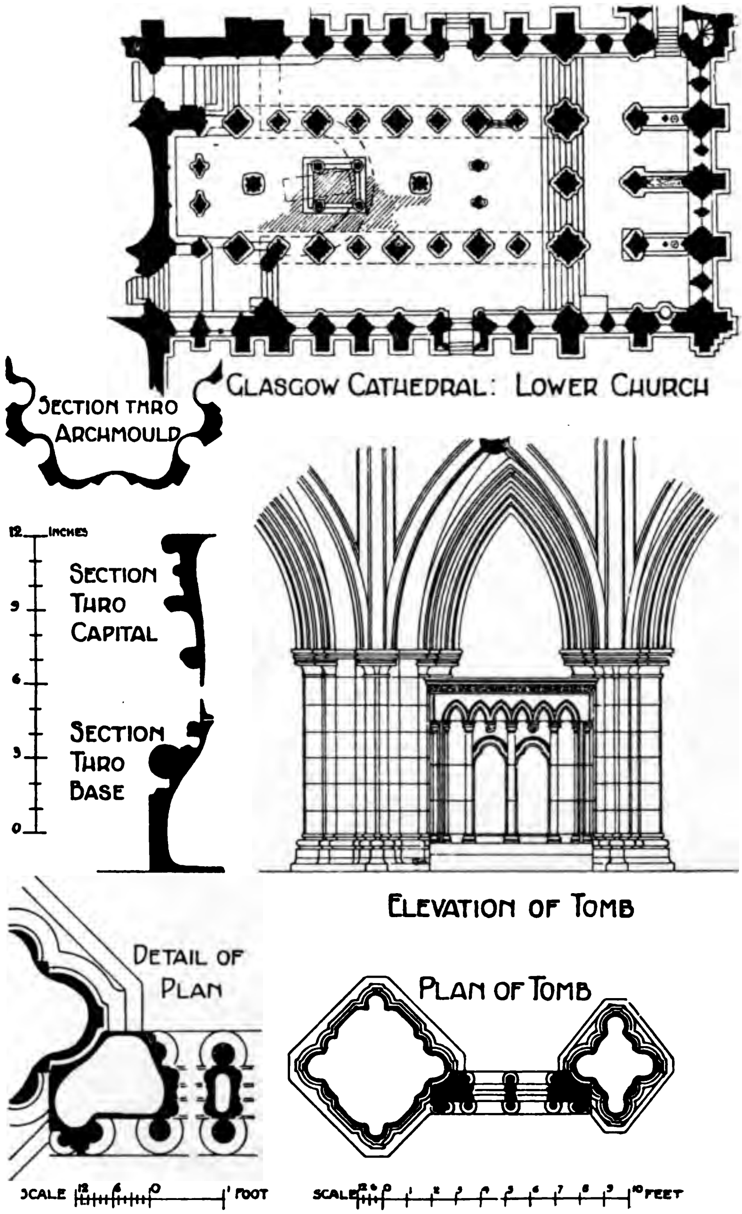
opening on the south side was also examined. The wall there was found to be as originally built, thus proving that the north arch is the true site.

The stones of the tomb which have been preserved are the sill stone with the bases of the columns; one stone of the east and west jambs and of the centre mullion of the arcade; and the great stone, now broken in three pieces, on which the two trefoil headed arches and the capitals of the columns are wrought. The stone cornice has disappeared, but it may be that the drawing here shown approximates to the original design. The whole work, on both sides, is finely executed; the mouldings are intricate; and there still remain a few traces of the colour decoration. The tomb was probably erected about the middle of the thirteenth century.

A suggestion may be offered as to whose grave and monument this was if attention is now directed to the unique sculptures in the vaulting of the north aisle of the crypt. The head of a bishop is carved upon the east side of the boss in line with the centre of the north entrance to the crypt. This is doubtless a portrait of the builder-bishop, William de Bondington, who died in the year 1258. The underside of the boss is designed as a wreath of foliage, with a man's face sculptured in the recessed centre. The hair is shown worn long behind, and is fashioned, on the brow, as a plaited and curled fringe. The nobles are represented with their hair dressed in this fashion in an illustrated life of S. Thomas, the Martyr, drawn by a Frenchman in England, between the years 1230 and 1260. The boss on the west side of the north porch is carved as a wreath of foliage with the exquisitely sculptured face of a woman in the deeply recessed centre. A king's head is represented on the east side of the boss in the second bay from the north porch, and this is doubtless a portrait of King Alexander II., who died in the year 1249. These carvings are unmistakable portraits. The bishop and the king are readily identified. The suggestion is now submitted that the male and female heads are portraits of David Comyn, Lord of Kilbride, and Isabella de Valoniis, his wife, whose magnificent gift to the Church of Glasgow of territory in the forest of Dalkarn was made before the year 1250. The tomb may be that of this Lord of Kilbride, or of his widow, Isabella de Valoniis.

(The illustration has been drawn to my instructions by my assistant Mr T. A. Macadam).

PLATE III.



GLASGOW CATHEDRAL: LOWER CHURCH
SECTION THRO ARCHMOULD
12 INCHES
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Duns Scotus: his Life and Times. By JOHN EDWARDS.

[Read before the Historical and Philological Section, 15th March, 1905.]

THE light shed upon the present, by the earnest and unbiased study of the past is no *ignis fatuus*, no will-o'-the-wisp, leading into the bogs and bunkers of false judgment and error. It is a truism that the scrutiny of no past period is barren of lessons of real value for the present, and that however unpromising at a first glance the ground may appear, the searcher after truth, who perseveres in digging, is rewarded by gems in unexpected places, and by finds of precious metal amid rocks of flint and quartz.

In addition to this, it is recognised that the philosopher and poet are modified and conditioned by the complex forces of society, political, social and religious, which go to the making of the times in which they live. As Sir Leslie Stephen has remarked: "We know Dante, and understand his position the more thoroughly, as we know better the history of the political and ecclesiastical struggles in which he took part, and the philosophical doctrines which he accepted and interpreted; and conversely, we understand the period the better when we see how its beliefs and passions affected a man of abnormal genius and marked idiosyncrasy of character." It is hardly necessary to remind you that the philosopher, no less than the poet, is a complex product largely influenced by the action of the forces of early training and habit, and the ideas current in the society and time in which his lot is cast, as well as by the inner workings of his own intellect upon the problems of being and knowing, of mind and of matter. He puts the thoughts, the beliefs, the scepticisms of the age into more distinct shape, he impresses them with the stamp of his own personality, and attempts with more or less success to justify them or to modify them. He states the problems that are exercising the thinking minds of the period, and sometimes even those that have little thought behind them, and he gives his contribution towards their solution. Hence to study his environment adds to our knowledge of the man, his excellences and limitations.

The times of the Schoolmen are, on their philosophic side, to

many, synonymous with endless prolixity and deadly dulness. Yet they are times which, when examined more closely, are found to have been themselves characterised by much stirring of the human intellect, and fraught with the promise of future advance in genuine knowledge and culture, however much they may seem, when looked at from the vantage-ground of the present time, to have been filled with the dull and never-ending murmurs of tiresome disputings and logical hair-splittings,

> "Where entity and quiddity
> The ghosts of defunct bodies fly.[1]"

Although the founder of the Franciscan Order—a simple layman—despised books and book-learning, and looked upon intellectual culture as a snare which was preventing the Religious Orders already established from evangelising the world around them, yet within fifty years of its institution his Order had become a pioneer in science, and his followers had founded a school of philosophy. So true is it that in mental and spiritual as in material things—"Naturam expellas furca, tamen usque recurret."

Few of us live, or are likely to live in times so stirring, or to take a large part in deeds so strenuous, as to give a new word from our patronymic to the English language, as Captain Boycott did, but it has fallen to the lot of Joannes Duns Scotus the philosopher, not only to found a School of Philosophy, but to give two new words from his own name, "Dunce" and "Scotist," to the language.[2]

No man has been more praised, or has kindled more enthusiasm among his followers. As a sample, take the following words of a learned writer of the seventeenth century—"Tam stupendo fuit ingenii acumine, ut paucos pares habuisse ulla aetate censeatur," and again, "Dux et signifer invictissimus.[3]" A modern French author has characterised his philosophical system thus "if not the deepest, at least the most original which medieval times have left us.[4]" On the other hand no writer perhaps has been more condemned or treated with greater con-

[1] Butler, *Hudibras*, I. i. 145.

[2] The word "Dunce" in Dr Murray's *New English Dictionary* is followed by an interesting paragraph tracing its development.

[3] Dempster, *Histor. Eccles. Gentis Scotorum* (Banna. Club) I. 227.

[4] Hauréau *Hist. de la Phil. Scol. 2e part*, t. ii. p. 173.

tumely: "Wee have set Dunce in Bocardo and have utterly banished him Oxford for ever with all his blynd glosses, and is now made a common servant to every man, fast nayled up upon posts in all common howses of easement, *id quod oculis meis vidi.* And the second time wee came to New College, after wee had declared your injunctions, wee fownd all the great Quadrant Court full of the leaves of Dunce, the wind blowing them into every corner; and there wee fownd one Master Greenefeld a gentleman of Buckinghamshire gathering up part of the said book leaves (as he said) therewith to make Sewells or Blaunshers to keepe the Deere within the wood, and thereby to have the better crye with his hounds.[1]" Rabelais speaks of the "Barbouillamenta Scoti,[2]" and a modern writer of "son jargon, son langage tenebreux.[3]"

> "What is the end of Fame? 'tis but to fill
> A certain portion of uncertain paper.[4]"

Had our Philosopher been content to fill during his lifetime fewer quires, it is possible that the leaves might have been left undisturbed to gather cobwebs on upper shelves of College libraries.

From what has now been said it is evident that we have to deal with an interesting personality. Is it possible to get in any way near to him now? Have we any means of knowing what manner of man he was? I fear these questions must be answered pretty much in the negative, and yet we may glean a few facts, and possibly draw a few inferences, and thus the attempt may not be altogether fruitless.

In opening the twelve goodly folios in which Father Luke Wadding has collected a large part of the works—genuine and doubtful—of Joannes Duns Scotus, the first feeling that strikes one is envy of the industry that produced so much, and admiration of the faith in man's mental digestion that made it possible to believe that readers would be found to peruse them. The faith has been justified, for readers have been found, in varying numbers, in the four centuries which have passed since portions

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[1] Wood, *Annals*, II. p. 62, quoted by Rashdall, *Universities of Europe in the Middle Ages*, II., 533 Note.

[2] *Pantagruel* l. ii. c. vii., quoted by Pluzanski, *Essai*, p. 4.

[3] Hauréau, *op. cit.* 2e part, t. ii., p. 242.

[4] Byron, *Don Juan*, c. 1, stanza 218.

of Duns Scot's works were first given to the public, and in 1890, at Paris, there was published a new edition in twenty-six volumes quarto, which I see from a bookseller's catalogue fetches a good price in the market.

The century which may be conveniently dated from the accession of St. Louis (Louis IX.) of France in 1226 was a period of great activity in the department of philosophic literature over Western Europe. As M. Gaston Paris remarks "The University of Paris," founded between 1150-1170, "became the intellectual centre of Europe.[1]" Translations of Aristotle from the Arabic into Latin had made their appearance in Spain, and had along with the works of the Arab Philosophers, Avicenna and Averroës, exercised a very stimulating influence on Western thought. Heretical poinions alarmed the Church, and the religious and scholastic spirit threatened to come into serious antagonism.[2]

It is outwith our subject to go into any discussion of the gradual adjustment brought about largely through the cautious Dominican doctor, Thomas Aquinas.

Our subject is historical, not philosophical, except in so far as history may be said to trench upon philosophy. It leads to look for a little at the career, so far as it can be known, of one of the followers of Saint Francis, and founders of a Mediæval School of thought. At first sight it may seem rash to attempt to say anything regarding a writer, of whose life the ascertained facts are so scanty, but if a few of the legendary fictions can be dissipated, and some of the more probable propositions restated, something is gained.

The year of his birth is uncertain. All that can be affirmed is that he was born in the latter half of the thirteenth century. Regarding the place, there has been much controversy, and he is claimed as a Scotsman, Irishman, and Englishman. It is agreed among all his biographers that he lectured at Oxford about the year 1300. Bartholomew of Pisa says: "He first of all at Oxford in England lectured on the Sentences; thereafter at the University of Paris.[3]" His call from England to Paris as a Bachelor of Divinity to receive the Chancellor's licence to "incept"—after which formal ceremony he was entitled and ex-

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[1] *Mediæval French Literature*, p. 97. [2] *Cf.* Rashdall, *op. cit.*, v. I., p. 361.

[3] Wadding, vi., p. 48.

pected as a Doctor of Divinity to lecture—is dated in December, 1304,[1] and we will speak of it later.

Can any cogent reasons for claiming our philosopher as a native of Scotland be put forward? The fact that after the middle of the sixteenth century Scotland had become a Protestant country caused subsequent Scottish writers to look with less favour than they would otherwise have done on one who was considered a buttress of the Roman Catholic faith. Hence in this matter Ireland had its own way to a large extent, and his Irish Editors, according to their national habit of laying claim to all the good things of this life, have made him a compatriot of their own. For example, Father Luke Wadding, an Irish Franciscan Friar, who, in 1639, published at Lyons the principal edition of his Works, in a life of the Author claims him as an Irishman born at Downpatrick in the North of Ireland. In this he follows an earlier writer, Maurice O'Fihely, Archbishop of Tuam, a Franciscan, who, in 1497, edited a "Commentary on the Metaphysics of Aristotle," which he supposed to be the work of Duns Scot. In the preface he claims him as a compatriot. But he is wrong as to the Author who in a note at the end of the book calls himself a pupil of Duns, whom he describes as *Natione Scotus.* This unknown follower is thus a fourteenth century witness to our philosopher's Scottish origin.[2]

It has also been said that he was born at Dunstane in Northumberland, and tradition points out the ruins of the peel tower where he first saw the light.[3] A recent learned writer whose work on "the Universities of Europe in the Middle Ages," is a perfect mine of information, has said:—"Both the two great Scholastic innovations of the fourteenth century—the revival of realism in a totally new form by Duns Scotus and the Nominalistic reaction headed by Ockham—had their origin probably in Oxford, certainly in English minds," and he continues, "Nearly all the later Schoolmen of any importance were Englishmen or Germans educated in the traditions of the English nation at Paris.[4]" Another English Historical Writer, the late Professor Brewer, to whom students are all much indebted for his exceed-

[1] Little, *Greyfriars in Oxford,* p. 220.

[2] *Vide Dict. National Biog.* vol. xvi., p. 216.

[3] Rashdall, *op. cit.* II. 531.

[4] Rashdall, *Universities of Europe in the Middle Ages,* vol. II., p. 529.

ingly luminous Introduction to the first Volume of the Rolls Series on the Franciscans (*Monumenta Franciscana*, vol. I., p. lxxxi.), says—"Italy produced its Aquinas, a great organiser like the Roman himself, its Bonaventure, in whom St. Francis reappears in a shape more learned, if not more spiritual, Germany its laborious Albertus Magnus, Spain its Raymond Lully, the representative of Spanish adventure and Spanish genius. But no nation can show three Schoolmen like the English" [Roger Bacon, Duns Scotus, and Occam], "each unrivalled in his way, and each working with equal ability in opposite directions." Professor Little in his most valuable volume, *The Greyfriars in Oxford*, is more cautious. He says (p. 219 n.), "there is no evidence as to the place of his birth (the note which Leland triumphantly quotes—Merton Coll. MS. 59—was written in 1455, and contains the baseless statement that he was fellow of Merton College); and the only evidence of his nationality is the name 'Scotus' and a note in the Catalogue of the Library at Assisi written 1381, 'Opus super quatuor libros sententiarum magistri fratris Johannis Scoti de Ordine Minorum qui et doctor subtilis nuncupatur de provincia Hiberniae.[1]'" This note is the one serious obstacle to the Scottish case. It is of the latter half of the fourteenth century, and therefore early, but it may be observed that against its authority there are several considerations of a valid character to be urged.

First, the name Scotus had ceased to be applied to a native of Ireland before the time of Alexander III., and the whole kingdom having been consolidated under him, the Lothians came to be included in the term "Scotia" which had previously only extended as far south as the Firth of Forth.[2] Thus Berwickshire was part of Scotland before our philosopher's time. This can be easily proved from contemporary writers, and probably one clear instance will suffice. It is taken from the records of the Order to which Duns Scot belonged. Thomas of Eccleston in his account "of the first coming of the Friars Minors into England," has occasion to refer to Brother John de Ketene (about the year 1239), and he says of him that he had been minister of Scotland (*Scocie*), and was made minister of Ireland (*Hibernie*). All competent authorities are agreed that Eccleston wrote his treatise

[1] Little, *The Greyfriars in Oxford*, p. 220 n.

[2] *Cf.* Skene, *Celtic Scotland*, vol. I., passim.

De adventu Minorum in the time of Henry III., and this is established by references to contemporary events in the work itself.[1]

Then, coming down to the beginning of the sixteenth century we find in John Major's *History of Greater Britain* a very definite statement regarding our philosopher's birth and career. Major begins the 16th chapter of book IV. with a notice of Richard Middleton, and as I think it will be found that Major's evidence is important, we may be permitted to quote his account in full. "About this time lived Richard Middleton, whom the Gauls name de Media Villa. He published four by no means despicable books upon the Sentences with Questions of great research. I do not recollect whether he studied at Oxford or Cambridge, but he was an English Briton. About the same period, but subsequent to him, wrote John Duns 'the Subtle Doctor,' a Scot of Britain belonging to the village of Duns eight thousand paces distant from England and from me (*i.e.*, my birth place) seven or eight leagues. Two Scottish Franciscans took him as a boy already grounded in grammar to Oxford, because at that time there was no University in Scotland. And through the favour of those two Brethren he was introduced into the Franciscan Convent at Oxford, and thus made his profession as a follower of the Blessed Francis. He was a man of profound intellect and a keen controversialist, accordingly he was not undeservedly styled by the appellation of 'Subtle.' He so advanced at Oxford, that on the Metaphysics and the four books of the Sentences he has left us written records worthy of the study of posterity, which written work is commonly known as the *Opus Anglicanum* or *Oxoniense.* Thereafter being called by the Minorites to Paris, he published another course of lectures on the Sentences less diffuse and more fruitful than the former, which latter work we have lately caused to be printed with metal types. Last of all, he repaired to Cologne and there died at a comparatively early age.[2]"

On reading this short sketch one is struck with the air of truthfulness about it. We notice that in speaking of Middleton, Major does not venture to make rash statements, but is careful when he is not sure of the facts to say so. There is no legendary

[1] *Mon. Franc.*, I., lxxii.

[2] Major, *Historia Majoris Britanniæ* (1740) pp. 170, 171.

element such as the later Irish writers indulge in. We must also bear in mind that John Major had very good opportunities of learning the truth about Duns Scotus. Although he lived, it is true, two centuries later, yet his birth place, near North Berwick, was not very far from Duns, so that he would in his youth hear the talk of the country-side regarding the philosopher. Then Major, to complete his education, studied at Oxford, Cambridge, and Paris, taking his degree as Doctor of Theology in this last University in 1505, and lecturing much in the same way as Duns had done, though with less renown than his more famous predecessor. I submit therefore, and I am glad to say that Professor Little now agrees, that Major's evidence is more valuable than that of the anonymous scribe who compiled the catalogue in 1381.

The case for England is a somewhat slender one, and turns entirely upon the authority to be given to a note or colophon appended to a MS. belonging to Merton College, Oxford, written in 1455 according to Dr Rashdall[1]: "Explicit lectura doctoris subtilis . . . scilicet doctoris Iohannis Duns nati in quadam villicula parochie de Emyldon vocata Dunstan, in comitatu Northumbrie, pertinentis domui scolarium de Mertonhalle in Oxonia et quondam socii dicte domus." Dr Rashdall mentions that the late Bishop Mandell Creighton had pointed out to him "that this very probably represents only the conjecture of some scholar from Embleton (a Merton living) who was familiar with the Castle of Dunstanburgh and the hamlet of Dunstan in that parish, where is an old manor house with a 'peil tower,' which local tradition makes his birthplace.[2]"

Dr Creighton's very acute conjecture will, at all events among a Scottish audience, be received as disposing of this uncorroborated entry, which makes, as has been pointed out, a serious blunder in the statement that he was a Fellow of Merton in the face of the College statutes which prevented Monks or Friars from holding this position.[3] Walter of Merton, the founder, compiled his "rules for a College of secular clerks," and "to his house he would admit no 'religious' person" as Miss Bateson

[1] Rashdall, *The Universities of Europe in the Middle Ages*, vol. II., p. 531, n. 2.

[2] *Ibid.* P. 531, n. 2. A very interesting notice of Embleton Parish is given by Mrs Creighton in the recently published life of her distinguished husband.

[3] Rashdall, *loc. cit.*

reminds us.[1] Thus a short statement which contains one palpable error is open to grave suspicion.

I have purposely, in this discussion, avoided bringing the learned Dempster forward as a witness, because one is reluctantly compelled to arrive at the conclusion that his support is not calculated to strengthen the Scottish position. It is right to say, however, that he shows great acumen in his attack on the English and Irish claimants, and his life of Duns in his Ecclesiastical History is an interesting sketch, and if one could depend on a statement made in it, would probably settle the question of Duns's birth. He states that Antonius Andreas, a contemporary friar and follower of the Subtle Doctor, who died twelve years after him, in the colophon to a work of his own, thus refers to his master: "that most subtle and excellent doctor, whose fame and memory are in benediction, and who has filled the whole world and caused it to resound with his sacred and profound science, namely, Joannes Duns, who was by birth a Scot, by religion a Friar Minor." This would be conclusive, but unfortunately it is not fully borne out by the facts as hitherto disclosed. Among the MSS. of Corpus Christi College, Oxford, as Mr Little tells us, there is a MS. belonging to the end of the sixteenth century written by William Vavasor, a Francisan Friar of Oxford and Doctor of Divinity. This MS. "at folio 46 contains *Antonii Andreæ tractatus de tribus principiis naturalibus*,[2] but so far as examined it contains no statement regarding Duns Scot such as Dempster makes. Of course, some hitherto unrecognised MS. of Antonius Andreas may yet be found which will corroborate Dempster's assertion.

A rather interesting question from a philological point of view is raised by one of the Irish Editors of Duns Scot's Works, Hugo Cavallus (Hugh MacCaghwell). In his Commentary on the fourth Book of the Sentences, Scot, in order to point out lying vagabonds, uses the word "trutani,[3]" and we are told that this word is of Irish origin. Dr Pluzanski observes that this word is the Gaelic *trudanach* or *truaghan*, *poor*, and that both France and England had already, before Duns Scot's time, adopted the word *truant.* The word occurs, as can be seen from Ducange, as early

[1] *Mediæval England*, p. 368.

[2] Little, *Greyfriars in Oxford*, p. 130, note 2.

[3] In 4th Sent. D. 15, q. 2, No. 24.

as 1227.[1] It therefore proves nothing. The Irish Editors are, it seems, somewhat at a loss for arguments to support their thesis of Scot's Irish birth when they are compelled to employ the following: In his lectures on the twelve books of Aristotle's Metaphysic Duns Scot (book 7, text 7) uses the following words. "Into the definition of 'white' the idea of man does not of necessity enter, but it is otherwise in the definition of St. Francis or St Patrick." "Behold the cry of the heart! see the names which come unbidden to the lips of the Irish Greyfriar[2]!" Thus comments father Wadding. But one may be permitted to observe that, even putting aside the fact that these lectures bear to be notes taken by Antonius Andreas an Aragonese Franciscan, there is nothing strange in a Scotsman in the year 1300 citing as a good saint, St Patrick.

We may now dismiss the question of Duns Scot's birthplace with the remark that it seems historically safe to reckon him one of the distinguished names on the roll of Scottish Metaphysicians, no unworthy forerunner of Reid and Stewart, of Brown and Hamilton, of Ferrier and Caird. In fact we may feel sure that M. Renan is right when he says, "those authorities who assert that Duns Scot was born in Scotland are by far the most numerous and the most weighty.[3]

When did Duns Scotus enter the Franciscan Order? Major declares that it was in his early youth, and there is every probability in favour of this view. But only one thing is certain, namely, that it was at Oxford that he completed his studies and began to teach.[4] One of the fabulous stories, which is not retailed by John Major, be it observed, is that his lectures were so popular that soon thirty thousand students flocked around his chair to drink in his words of wisdom. His lectures were not altogether of the class known now-a-days as "popular lectures," but the mental digestion of the middle ages was stronger than ours. I need only mention that ordinary lectures usually began at six o'clock in the morning, and that to the mediæval student breakfast was a luxury generally omitted, in order to show the strenuousness of his life on the side of study. We are apt to think of the university student in the middle ages as a clerk beginning every day with early mass, but

[1] Pluzanski, *Essai sur la Philosophie de Duns Scot* (Paris 1888), p. 12.

[2] Pluzanski, *op. cit.* [3] *Histoire Littéraire de la France*, T. xxv., p. 406.

[4] Pluzanski, *op. cit.* p. 14. [5] Rashdall, *op. cit.*, II., 652.

in the thirteenth and early fourteenth centuries only on Sundays and Holy-days did he as a rule attend mass. The student was a clerk in the sense that he was unmarried, had adopted the clerical dress and had submitted to the tonsure, but he was not necessarily even in minor orders.[1]

When Duns Scotus was at Oxford he had not yet taken the Doctor's or Master's degree, and therefore his lectures would be what were called "extraordinary," and these were usually delivered in the afternoon.

In 1300, our philosopher appears as "Johannes Douns" among a number of Grey-friars presented to the Bishop of Lincoln in order to receive licence to hear confessions. According to the Rules of the Order he must have been at this date at least thirty years of age.[2] Bishop Dalderby refused him licence. The reason of this refusal is probably the rather strained relations between the Bishops of Lincoln and the University. At the beginning of the thirteenth century the University of Oxford was ecclesiastically entirely subject to the control of the Bishop. During the next one hundred and fifty years it was gradually emancipating its Chancellor and itself from this dependence. The process, as can be easily understood, was not without friction, and during Bishop Lexington, Bishop Sutton, and Bishop Dalderby's occupancy of the See the disputes between the parties were chronic. The Friars played an important part in achieving this emancipation, and from their influential position as a comparatively new and active religious and intellectual force in the country, were bound to win in the ultimate result. At this time Friar Walter de Wynterburn was Confessor to the King of England, and they had a good friend in Archbishop Peckham, one of themselves, and therefore their strong supporter. He had lectured both at Oxford and Paris, was a Doctor of Theology of the latter University,[3] and therefore knew and sympathised with the claims of the University of Oxford to manage its own affairs. John Peckham's treatise on optics (known as *Perspectiva Communis*) was one of the mathematical text-books used in the University of Paris.[4]

One may refer in passing to a difficulty which had a tendency

[1] *Vide* Rashdall, *op. cit.* II., 646, and authorities there cited.

[2] Little, *Greyfriars in Oxford*, p. 220.

[3] *Mon. Fransc.*, I. 537.

[4] It was written in 1280. See Rashdall, vol. I., p. 442.

to recur between the Universities and the Mendicant Orders. The Universities required every student before applying himself to the higher sciences (of which Theology of course was one) to pass through the Arts course—the well-known Trivium, Grammar, Logic and Rhetoric, and the Quadrivium, Arithmetic, Astronomy, Geometry, and Music. The Friars on the other hand, according to the Rules of their Orders, gave this secular instruction to their own young members within the convents, and by their own teachers, and presented them ready to pursue their theological studies at the University. In order to enable them to do so, the University granted "graces" or dispensations to those Regulars who were thus presented. Mr Little has printed a number of the "supplications and graces" granted to the Franciscans in the 15th century and first quarter of the 16th century.[1] The case of Walter Goodfield, Warden at Oxford, may be referred to as showing the number of years spent in study before obtaining the Degree of Doctor of Divinity. In his "supplication" of 1506 he states that he has studied logic, philosophy, and theology for twelve years. In his second supplication, eighteen months later, he declares that he has spent fourteen years in study. In December, 1507, he is admitted Bachelor of Theology. It is not till July 1st, 1510, that he is admitted to the Degree of D.D. after upwards of sixteen years spent in study.

To return to Bishop John Dalderby, whose refusal to licence Johannes Duns, (whom we identify with Duns Scotus) to hear confessions, brings him into our narrative, he figures in one of the *Contes Moralisés* of Friar Nicholas Bozon,[2] as follows :

"The worthy man John Dalderby, Bishop of Lincoln, pointed out to the Abbot of Eynsham who was dining with him at his palace at Banbury, a certain gentleman who happened to be present, and he told him that this gentleman was Executor of an Ecclesiastic who had just died in the Bishopric, and that he had come for the Bishop's advice in the following circumstances: 'The deceased' said he, 'was Procurator to the Knights Templars at the Court of Arches in London,[3] and had from them

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[1] Little, *Greyfriars in Oxford*, p. 337.

[2] Toulmin-Smith, and Meyer, *Contes Moralisés de Nichole Bozon, Frère Mineur*, p. 181.

[3] St Mary-le-Bow, (S. Maria de Arcubus).

free board and lodging [bouche a court] for himself, and a servant, and a horse, as well as robes and an annual pension. In addition he had been presented to a very good living, and thus as long as he was able to drag himself to the Court of Arches, he spent nothing, but lived upon the Templars. And when he was unable any longer to do so, he retired to his parish and dwelt there miserably, entertaining none of the neighbours and never eating a good dinner. At last, feeling his end approaching, he made his testament which disposed of three hundred pounds, and he handed over the money in trust to his Executors. But at the end of his will he added these words :—'Ad hec autem omnia remanent octo sub cathedra.' This proved a puzzle to the Executors which the dying man declined to explain. On his death, feeling sure that the words were not without meaning, they quietly searched the whole house up and down, and discovered a chair in a little dark chamber which his predecessors had used as a wine-cellar, and had never kept locked. Under this seat, stowed carefully out of sight, they found a coffer with £8,000 sterling in it. 'Accordingly this gentleman who is the principal Executor,' continued the Bishop, 'has come here to obtain our advice as to the disposal of the treasure.' The Bishop exclaimed as he came to this point in the story 'Eight thousand pounds! eight thousand pounds, Sir Abbott, had he in his treasury, and he never gave a good dinner in his life!' When the Abbott heard of this folly he laughed heartily, and calling the Executor advised him to make himself and his Co-trustees comfortable with the spoil. But the Bishop commanded him to give a suitable sum in alms for the good of the dead man's soul, under peril of his own soul's salvation."

This story is introduced merely as giving a contemporary glimpse of the Bishop and his views on the subject of accumulating wealth for others to enjoy. He held the See from the year 1300 till 1320. The Bishops of Lincoln had a residence at Banbury in Oxfordshire from the eleventh century, if not earlier.[1]

At Oxford our Philosopher composed what are without doubt his principal works—his first Commentary on the Master of the Sentences known as *Scriptum Oxoniense* and the *Questiones disputatae de rerum principio.* These are to be found in volumes IV., V., VI., VII., VIII., IX., and X. of Wadding's edition. The

[1] See *Contes Moralisés*, p. 296.

Scriptum Oxoniense—Questions on the four books of the Master of the Sentences (Peter Lombard)—was left unfinished by Duns Scot, and in Wadding's Edition the latter part of the fourth book is transferred from the *Opus Parisiense.*[1]

His call to Paris in the end of the year 1304 has been already referred to. The letter of Gonsalvo, Minister General of the Franciscan Order to the Warden of the Convent at Paris is the sole contemporary historical document regarding Duns Scot which has come down to us. In that letter the Minister-General is loud in the praise which he bestows on the dear father in Christ-Joannes Scotus, regarding whose praiseworthy life, excellent learning, most subtle intellect, and other distinguished qualifications, he is fully informed, partly through universal report, and partly through long experience. He accordingly instructs the Warden of Paris to present Scot after Father Aegidius to the Chancellor for the purpose of receiving licence to incept as Doctor of Divinity at Paris.[2]

Some difficulties have been raised regarding this letter. We have not got the original, only Wadding's copy, and that probably not a very correct one. For example, it has been asked how can the Minister-General speak of his "long experience" of the virtues of a young man of only a little above thirty, and who, moreover, had lectured in a somewhat remote part of the Christian world, or at least remote from Ascoli-in-the-Marches from which the letter is dated? I do not think there is much in this objection. England was in closer touch with Italy in the middle ages than we sometimes imagine. The Church, with its centre in Rome, brought ecclesiastics of all grades, secular and clerical, into continual intercourse with Italy, and moreover there was considerable commercial business between the two countries. Much of this business was done by the monks. "It appears that in 1284 many monasteries in Great Britain had agreed to sell their wool to the Florentines.[3]" It was quite natural that with all this ecclesiastical and commercial intercourse between the two countries, the fame of the distinguished Franciscan philosopher should have at once reached the ears of the Head of his own Order. In fact, it would have been strange if the opposite had been the case.

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[1] Pluzanski, *op. cit.*, p. 29. [2] Little, *Greyfriars in Oxford*, p. 220.

[3] Cunningham, *Growth of English Industry and Commerce*, p. 198.

Duns Scotus seems to have remained in Paris for a comparatively short time, certainly not more than four years.[1] During the period of his residence, he lectured as required by the Statutes of the University on the Sentences of Peter Lombard, and those lectures have come down to us under the name of *Reportatorum Parisiensium libri quatuor.* His subject at Paris was thus the same as that which he took up at Oxford, but as we now have it, the *Reportata Parisiensia*, is, as John Major puts it, more condensed, more of a summary, than the Oxford Lectures. It forms the eleventh volume of Wadding's edition.

The Franciscans have naturally cherished the memory and renown of their great Philosopher, and thus several fables have been put forward regarding his career in after years. It is said that he was at Paris the invincible champion against the Dominicans of the doctrine of the Immaculate Conception of the Virgin—a doctrine which came to be distinctively a Franciscan tenet. The statement is made that a full-dress official debate between the Doctors of the two orders on the subject had been arranged, and that as Duns Scot journeyed towards the University for the purpose of taking part in it, he passed a statue of the Virgin. He prostrated himself in prayer for her aid in the forthcoming debate. She bowed towards him graciously and promised him victory, supplying him with hundreds of syllogisms proving the doctrine incontrovertably. As vouching for the truth of the story, the image remained in a bowing position ever after. He went on and carried all before him in the argument, so much so that the University is said to have been officially convinced, the surname of "the subtle Doctor" was awarded to him, and the University determined to admit to its degrees in future no one who declined to swear to uphold the Immaculate Conception.

This story is without foundation in fact. One needs only to look at what our philosopher says himself in order to prove this. After mentioning that there are three possible methods in which freedom from Original sin may been conferred on the Virgin: (1) by innate and complete exemption, (2) immunity conferred on her after an instant spent in sin, and (3) immunity granted after some longer time in sin, he proceeds, "But God only knows which of these methods that have been shown to be possible

[1] Pluzanski, *op. cit.*, p. 20.

was adopted. If it is not repugnant to the authority of the Church nor to Scripture, it seems probable that the most honourable is to be attributed to Mary.[1]" This is a cautious opinion, very different from the tone of a zealous champion. The truth is that the doctrine was in a nebulous state in the thirteenth and first half of the fourteenth century, and there is no trace of a dispute upon the subject in the University of Paris before the year 1384, many years after Duns Scot's death.[2]

In the year 1308 he was summoned by the Minister-General of his Order to leave Paris and proceed to Cologne. Tradition says that on receiving this order he displayed all the Spartan virtue of the early Franciscans. He happened to be on duty outside of the Convent when the Order reached him; he started off straightway on his road to Cologne without returning to take farewell of the Brethren, or even to collect a few articles of clothing for the journey. Some one remonstrated, when the philosopher replied: "Pater-Generalis Coloniam ire jubet, non in Conventum ad salutandos fratres.[3]" [The Father-General orders me to go to Cologne, not into the Convent to take my leave of the Brethren.]

M. Renan is of opinion that the reason of the mission of Duns Scot to Cologne is to be found in the desire of the Franciscan Order to send one of its ablest men to confute the Begards and other sects which were rampant in that City, and thus stem the tide of heresy which was rising at that time.[4] These religious enthusiasts were largely a product of the same movement which had produced the Mendicant Orders themselves,[5] and as in homœopathy, similia similibus curantur, so if this view be accepted a Greyfriar appeared the best antidote to Franciscanism run-to-seed. According to Matthew de Veglia, our philosopher mixed freely with the crowd who came to the Cathedral to hear the sermons, and there when the Begards interrupted the preacher with loud shouts, he took them aside, and by his convincing arguments reduced them to silence.[6] One may feel disposed to

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[1] Duns Scotus, (Edn. 1477, vol. I., fol. 120, d. 121 a.) In Sent. III. Quæst. i., § 9 and 10.

[2] Pluzanski, *op. cit.*, p. 20.

[3] *Histoire Littéraire de la France*, vol. xxv., p. 407.

[4] *Op. cit.* [5] Pluzanski, *op. cit.*, p. 20.

[6] *Vita Scoti*, § xxx., quoted by Renan, *op. cit.*

conclude that the silence was caused more by inability to cope with the eloquence of the Subtle Doctor, than by conviction caused by the cogency of his arguments in the minds of the Begards.

It seems at least open to doubt if the view that our philosopher was sent to Cologne in 1308, merely to confute the heretics, covers the whole field. When we consider the tragic drama that was being enacted in France at this period by the arrest and torture of the Templars,[1] and the prominent part which the Mendicant Orders took in the suppression,[2] we may at least hazard the conjecture that Duns Scotus was not at all unwilling to get away from the centre of events so uncongenial to philosophic study, and that the Head of the Order was wise enough to see that his removal from the scene of hurly-burly was a proper step to take.

All the biographers are agreed that the philosopher did not live long to exercise his dialectic against the heretics of Cologne. He died on the 8th November, 1308, and was buried in the Greyfriars' Church in front of the Sacristy. His death appears to have occurred suddenly, and this may have given rise to the later and persistent story that he was buried alive, which has been presented by some writers with gruesome details of horror. Its truth has been vehemently denied by others, especially those belonging to the Order of Greyfriars.

If he was not buried alive, his ashes have suffered scant repose in the centuries that have followed. No less than five times have his remains been exhumed. First, in 1476 in the Pontificate of Sixtus IV., who was at that time promulgating a Bull in favour of the Immaculate Conception. His bones were then moved to the centre of the Choir. In 1509 the second removal took place when they were placed behind the great altar. The third exhumation took place in 1619 by order of the General of the Greyfriars, and on that occasion the ashes were gathered together, placed in a lead coffin and that in an outer wooden case, both being provided with a glass opening admitting of the relics being seen. In 1642 the Minorites altered the internal arrangements of

[1] The arrest took place in the autumn of 1307.

[2] The Papal Commission for examining the Knights-Templars met in various places in Paris. One of the religious houses in which it assembled frequently was that of the Friars-Minors, in January, February and March, 1310. (*Vide*, Michelet *Procès des Templiers*, T. I., 468, 484, 511, 529, 535, 548, 554; T. II. 3, etc.)

their Church and built a new Choir, and the coffin having been lifted it was placed in 1643 in this new Choir under a monument which M. Renan says "appears to have been somewhat mean." In 1706 occurred the fifth and last disturbance, when the proposed beatification of the philosopher was attempted by his Order. As the effort to make him a Saint failed, his ashes have been since allowed to rest in peace, but his monument was destroyed during the French Revolution.[1]

After our philosopher's death his fame, especially as the leading Doctor of the Franciscan Order, steadily increased, and "his authority," as M. Pluzanski remarks, "eclipsed that of Alexander of Hales and of Saint Bonaventure.[2]" From the Catalogue of Volumes belonging to the Cathedral Chapter of Glasgow made in 1432, we find that our Cathedral Library in the reign of James I. possessed many interesting MSS. Among others—"*Item*, a volume upon the IIIrd. and IVth. Books of the Sentences by Johannes Downs, 'the subtle doctor,' which begins '*Circa incarnationem.*'" A MS. of Duns in Balliol College, Oxford, has this *initium.*[3] The edition on the table is slightly different in the opening words of Book III. Upon the third shelf we come upon "the second book of Scot, the subtle doctor, containing in the first line of the second folio '*Creatura est.*'" So that our philosopher was evidently being studied in his own country, in Glasgow, even before our University was founded, and before we had a Franciscan Convent in our city.[4] We thus obtain unimpeachable testimony to his high position of authority in the fifteenth century in Scotland. Judging his character from his writings, he was a keen critic, who was only turned from scepticism by the real dread of having his books burned and their author imprisoned. In all mediæval systems of philosophy the attempt was made, because it was thought possible, to give a complete solution of all the problems of the universe, to reach by reason the principles of things, and answer the deep questions concerning the Divine nature and that of man. It is not our purpose, even if we felt qualified for the task, to enter into an examination of Duns Scot's philosophical system. Suffice it to say that the

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[1] I am indebted for these details regarding the successive exhumations to M. Renan's Article in *Hist. Litt. de la France*, t. xxv.

[2] *Op. cit.*, p. 25.

[3] Little, *Initia*, p. 39. *Circa incarnationem quaero primo de possibilitate.*

[4] Glasgow Convent was founded between 1473 and 1479.

view of Bishop Stubbs does not seem far from the true one, when he declares that "the whole array of modern philosophy, negative or positive, has not got nearer to the solution of the problem of existence than the Schoolmen of the Middle Ages.[1]"

Duns Scotus is not a writer whose works disclose the man. A diarist like the immortal Pepys and he stand wide as the poles asunder, and yet he cannot help lifting the veil and showing us the workings of a keen and eager intellect, that was steeped in all the learning of the age, and that took pleasure in marshalling in order all the arguments both for and against every proposition with which he felt himself called upon to deal. His was a master-mind, and as Mr. Hill Burton reminds us, "Duns Scotus still holds sway over the intellect of men, even in this active, conceited and adventurous age."

There are one or two references to contemporary events in the "*Scriptum Oxoniense.*" In the Prologue to the Commentary on the First Book of the Sentences occurs a reference to the weakness at that time and the impending downfall of the power of Mohamet. Duns Scot is setting forth the arguments for the permanency of Christianity as contrasted with the evanescent character of heretical sects, and he says:—"Should any one object that Mohammedanism is a permanent religion, I reply, it took its rise more than six hundred years after the founding of Christianity, and shortly, with Divine assistance, it shall be brought to an end. It has been much weakened in the year of grace 1300, and many of the followers of the Prophet have been slain, and still more put to flight, and to them applies the prophecy which predicts that that sect shall be soon brought to naught.[2]" This is supposed to refer to the great victory in the East in the previous year of the Knights-Templars in alliance with the Mongol King of Persia—Casan Cham—over the sultans of Damascus and Egypt, which enabled Casan and the Templars to enter the City of Jerusalem in triumph.[3] If this view is accurate, then the passage must have been penned before the final defeat and surrender of the Christians in October, 1302, were known in Western Europe. In this connexion it is interesting to note that, while in Wadding's edition of 1639, the date 1300 is distinctly

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[1] Hutton, *Letters of Bishop Stubbs*, p 307.

[2] Duns Scotus [1477 Edn.] in 1st Sent. Prolog., q. 2. See *Plate.*

[3] Addison, *Knights-Templars*, p. 444.

given, in the edition of 1477, on the table, the date is 1400 [MCCCC] and that the last C has been erased, when, or by whom, is unknown. I am disposed to believe that the clause with the date may be the work of some zealous editor who could not let slip the opportunity of attempting to prove from actual history the truth of prophecy. In the Commentary on the 4th Book of the Sentences he is said to refer to a Bull of Pope Benedict XI, which proves that the date of this part of the lectures is not earlier than 1303.[1]

There are in his writings, it is needless to say, no references to Scottish History, to Wallace and the War of Independence. I rather think that our philosopher comes before Huchown as being what Mr J. H. Millar calls "the first illustrious specimen of that much-vilified person, the Anglicised Scot,[2]" or to speak more correctly he is, as a philosopher, a citizen of the world to whom nothing human is foreign. Tradition credits him with a ready wit, and the story is told that the Duke of Burgundy, as they sat opposite each other at dinner, asked the philosopher "What is the difference between a Scot and a sot?" "There is only a table between them," was the immediate reply, and the boldness of the answer is thoroughly characteristic, and is equalled only by its pungent wit.[3]

[1] Pluzanski, *op. cit.*, p. 16. I have not been able in Wadding's edition t find this passage, although there occur references to various Popes, such as Alexander II. and Nicholas IV.

[2] Millar, *Literary History of Scotland*, p. 12.

[3] Chambers, *Book of Days*, I, p. 182.

Prologus

culmen auctoritatis obtinuit. ⁊ parū
post. quid est aliud qđ tam ingratū po
test eē opi atq̄ auxilio diuino q̄ꝫ tanto
labore ꝑdicte auctoritatī velle resistē.
vñ Gamaliel actuū 5°. Si est ex hoi-
bus ꝯsiliū h̄ aut opus dissoluet᷑. Si
vo ex deo ē non poteritꝭ dissoluere ne
forte ⁊ deo videamini repugnare. Et
Luc. 22°. ait dñs Petro. Ego rogaui
ꝓ te Petre ut nō deficiat fides tua. ⁊
tu aliqñ ꝯuersus confirma frēs tuos.
Firmitas .n. ecclesie i mēbris patꝫ p
illud Augꝭ. de utilitate credēdi. 8°. vul
gus marū ⁊ feminaꝝ ⁊c. Similē sen
tentiā dicit ꝯ eplam fūdamēti. Quis
n. tantā multitudinē ad pctā ꝓnā ad
legem ꝯriā carni ⁊ sanguini seruādā
inducēt nisi deus. Et ꝯfirmat᷑. quia se
cta iudeoꝝ nō manet in vigore sicut
ꝯ eos obijcit Aug⁹ in ꝑ sermōe de ad
uentu. Uos inq̄ꝫ cōuenio o iudei / Si
obijcit᷑ de ꝑmanentia secte machome
ti. R°. illa incepit plus q̄ꝫ sexcentū an
nis post legē xp̄i. ⁊ in breui deo coope-
rante finiet᷑. q̄ multū debilitata est an
no xp̄i m°. ccc. ⁊ ei⁹ cultores multi mor
tui ⁊ plurimi sūt fugati. ⁊ ꝓphetia dr̄
eē apud eos ꝙ cito finienda est secta
illa.

De octauo .s. de

miraculoꝝ claritate sic pꝫ. Non pōt
eē testis falsus de⁹. s̄ deus inocatus a
ꝑdicante scripturā ut ostendēt doctri
nam ei⁹ eē verā fecit aliqđ opus sibi
ꝓpriū. utpote miracula. ac p h̄ testifica
t⁹ ē illud eē veꝝ qđ iste ꝑdicauit. Cō
firmat᷑ h̄ p Ric. ꝑ de trini. ca°. 2° vbi
d̄. Dñe si ē error a te decepti sum⁹ nā
tantis signis ꝯfirmata sūt q̄ nō nisi p
te fieri possent. Q̄ si dicat᷑ miracula
nō fuisse facta. aut etiā ꝙ ipsa non te-
stant᷑ v̄itatem q̄a añxp̄s faciet mira-
cula. Contra ꝑmū dici pōt illa sñia
Augꝭ. de ciui. li°. 22°. ca°. 5°. Si ista mi-
racula facta eē non credunt h̄ nobis
vnū grande miraculūꝫ sufficit ꝙ iam
terraꝝ orbis sine vllis miraculis cre
didit. nota valde illud ca^m^. q̄a si q̄cq̄d
quod credim⁹ dicatur incredibile eē
non min⁹ est incredibile hoies inquit
ignobiles infimos. paucissimos. īperi-
tos. rem tā incredibilē. tā efficacit᷑ mū
do. ⁊ in illo etiā doctis ꝑsuadē potuis-
se ut mūdus illud credat sicut iā cre-
didisse videt᷑ nisi p illos aliq̄ miracu-
la fierent p q̄ mūdus ad credēduꝫ in
ducēt᷑. vñ subdit. Qui ꝓpt᷑ea exiguo
nūero ignobiliū infimoꝝ īperitoꝝ ho
minū credidit. q̄a in tam ꝯtemptibili-
bus testibus multo mirabili⁹ diuinitas
seipsa ꝑsuasit. Quid .n. incredibilius
q̄ꝫ ut ad legem ꝯriā carni ⁊ sanguini
doctores pauci ⁊ rudes ⁊ paupꝫres
possent plurimos potentes ac sapien-
tes cōuertē. quod spālit᷑ patꝫ de mul-
tis sapientib⁹ ꝑmo fidei rebellib⁹ po
stea ꝯuersis. ut de Paulo prius perse
cutore postea gentiū doctore. ⁊ de Au
gustino prius p manicheos seducto
postea doctore catholico. De Dio-
nysio ꝑus phō. postea Pauli discipu
lo. Et de Cipriano prius mago postea
xp̄ianissimo epō. ⁊ de innumeris alijs
cōuersis. Cōtra idem 2° dici pōt il
lud Augꝭ. de ciui. dei. lib° x° ca° 18°. an
dicet aliq̄s ista falsa eē miracula nec
fuisse facta sed mendaciter scripta. q̄s
quis hoc dicit si de his rebus negat
omnino vllis lr̄is eē credendū: potest
etiā dicē nec deos vllos curare morta
lia ⁊c. ⁊ ibidē de eodē. Si libris magi
cis sine qđ honesti⁹ putant theoricis
credūt: quid cāe est cur illis᷑ lr̄is nolūt
credē ista facta eē? Cōtra idem 3°.
q̄a quedā facta nō nisi a nimis ꝓter-
nientibus negari pñt. ut sūt miracula
facta a Siluestro corā Constantino
tā i curatiōe lepre ei⁹ q̄ꝫ in disputatio
ne eius ꝯ iudeos q̄ facta tā q̄ꝫ celeber
rima mūdum non latuerūt. Cōtra
3^m^ dici pōt ꝙ si q̄s inocat⁹ in testem
signū ꝯsuetū testificationis permittat
adduci ⁊ ꝑsens nō ꝯdicat. talis taci-
turnitas nō stat cū v̄itate ꝑfecta. mira
culū aūt ē tale signū dei ut testis. igit᷑ si
ꝑmittat miracula fieri a demonib⁹ nō
ꝯdicens annūcians .s. illa non eē testi-
monia sua. non videtur esse perfecte
verax. quod est impossibile. ⁊ per hoc
dr̄ ad illō de antechristo ꝙ ꝑdixit illa
miracl̄a faciēda nō eē testiōia v̄itatꝭ.

DUNS SCOTUS, WORKS. (Venice, 1477.)

Notes on Radio-Activity. By H. STANLEY ALLEN, M.A., B.Sc., being a Communication from the Mathematical and Physical Section.

[Read before the Society, 25th January, 1905.]

THE experiments described in the present communication were carried out by Lord Blythswood and the author, in continuation of the work of which an account was given to the Society during its last Session.

RADIO-ACTIVE GAS IN MINERAL SPRINGS.

It was shown that the mineral springs of Bath and Buxton contained radio-active gas, and in a note added to the former paper, December 15th, 1903, the opinion was expressed, as the result of further experiment, that the radio-activity of these waters was due to the presence of radium near their source. This view received speedy confirmation in the discovery by the Hon. R. J. Strutt that radium was present in the deposits left by the hot springs of Bath. This discovery was announced in a letter to the Bath Town Council, January 15th, 1904.

EXPERIMENTS WITH GAS COLLECTED AT THE SPRINGS.

In the experiments I have described with water sent from the springs, the amount of gas obtained was extremely small, and the consequent activity inconsiderable. More striking results were secured in experiments on samples of gas collected at the springs and forwarded to the Blythswood Laboratory in sealed Winchester quarts.

The ionisation current through the gas was measured, two brass wires passing through a paraffin plug being introduced into the bottle for the purpose. The wire in connection with the electrometer was provided with a brass guard-tube connected to earth.

Experiments commenced December 18, 1903, on Gas collected at the Buxton Springs by Mr J. W. Wardley.

Rate of leak between the two wires in air, 18 divisions in one minute, the charged wire being at 400 volts.

At 11 a.m., the rate of leak in the Buxton gas was 85 divisions in one minute. The rate of leak gradually increased till 1.40 p.m., when it reached a maximum value of 118 divisions in one minute.

The conductivity then diminished gradually, the activity falling to half value in about three-and-a-half days.

A smoothed curve showing the rate of decay of the activity is given in Fig. 1.

On removing the wires from the gas after 7 days they still

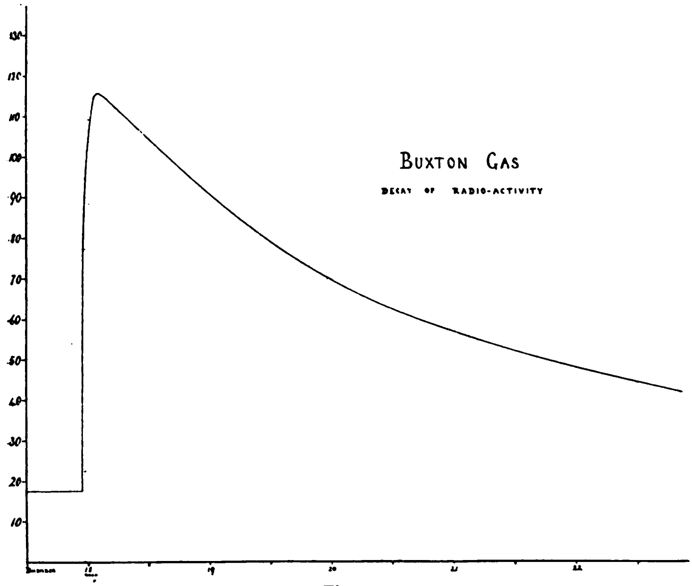

Fig. 1.

showed, when tested in ordinary air, a small amount of "induced" or "excited" activity.

Experiment commenced February 13, 1904, with Gas collected from the Springs at Bath and despatched February 10.

The rate of leak between the two parallel brass wires in the Bath gas was at the commencement as great as 209 divisions in 15 seconds. It was estimated that the current through the gas amounted to $6{\cdot}6 \times 10^{-12}$ ampere. The results of the observations, which were continued for over a fortnight, are plotted in Fig. 2. From the smoothed curve the time taken for the activity to fall to one-half of its value at any given time is found to be 3·5 days.

The radio-activity of the gas falls off according to an exponential law, the activity, I, at any instant being given by the formula

$$I = I_0 e^{-\lambda t}$$

The value of the constant λ in the case of the Bath gas is given by

$$1/\lambda = 435{,}000$$

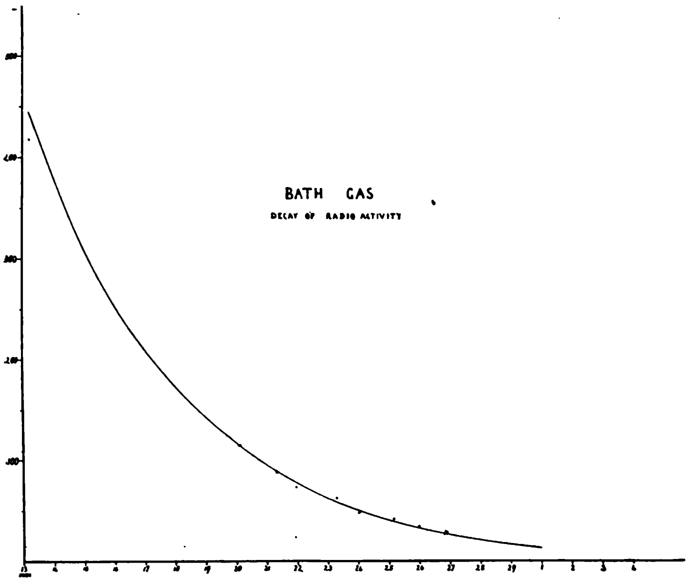

Fig. 2.

The corresponding value for the radium emanation, which loses half its activity in 3·71 days (Rutherford) is

$$1/\lambda = 463{,}000$$

while for the gas extracted from the Cambridge tap-water Mr Adams finds

$$1/\lambda = 425{,}000$$

These results show that the radio-active constituent in the gas from these springs is identical with the emanation from radium. (*Nature*, Vol. 69, p. 247, Jan. 14, 1904.)

EXPERIMENTS WITH MUD COLLECTED AT THE BUXTON SPRINGS.

A series of experiments was carried out with the object of

determining whether the mud deposited at the Buxton Springs contained radium in measurable quantities.

For these experiments a parallel plate apparatus, similiar to that used by Mme. Curie, was employed. The material to be tested was placed in a shallow tray of thin brass, resting upon the lower plate, and the ionisation current between the plates was measured.

In order to determine the ionisation current in absolute units the capacity of the system consisting of the parallel plates and the quadrants of the electrometer had to be measured. The capacity of the apparatus used for testing the Buxton mud was found to be ·000075 microfarad. To charge this capacity to a potential of one volt in one minute, the current necessary is $1{\cdot}25 \times 10^{-12}$ ampere. One volt was equivalent to a steady deflection of 157 divisions on the scale of the electrometer.

When mud from the Buxton Springs which had been dried over a bunsen burner was placed in the apparatus a small increase in the rate of leak was observed. This increase amounted to about 10 divisions in one minute, equivalent to a current of 8×10^{-14} ampere. Attempts were then made to concentrate the active constituent by chemical treatment, following the method employed by Mme. Curie in the separation of radium from pitch-blende.

One portion of the mud was treated with strong sulphuric acid, the liquid was decanted and the residue washed and dried. The residue after this treatment showed no activity. It was thought that the activity might be recovered through lapse of time, but a test made 13 days later showed that this was not the case.

Another portion of the mud was roasted with sodium carbonate. Tested after this treatment it showed a slightly diminished activity. The mixture was then treated with sulphuric acid, the insoluble residue was washed and dried and the filtrate was evaporated to dryness. Neither the insoluble residue nor the solid obtained by evaporation showed any appreciable activity.

It therefore appears that the samples of mud examined contained no appreciable quantity of radium. Their initial activity is probably due to the presence of a small quantity of the radium emanation (and its derivatives) which we know to be present in the waters from the springs.

It is probable that the emanation is given off by radium which is present in the deeper strata through which the waters of the Buxton Springs pass before rising to the surface.

THE PHOTOGRAPHIC EFFECT OF RADIUM RAYS.

In the paper already referred to I suggested that the photographic action of the radium rays might be due to the fluorescence which they excite in the glass plate or sensitive film. An experiment I carried out some months ago has convinced me that the photographic effect produced by the rays is too intense to be explained in this manner. The radium was contained in a small lead box fitted with an aluminium cover. A strip cut from an unexposed plate placed upon this cover showed a faint luminosity. I took a phosphorescent screen, coated with calcium sulphide, and by exposing it to light for a suitable period of time so adjusted the brightness of the phosphorescence that in the dark room it appeared to glow with the same intensity as the photographic plate.

Two strips cut from the same plate were then taken. Of these one was placed on the cover of the radium box, the other was placed with the sensitive film in contact with the luminous screen; and they were exposed together for forty minutes. After developing the strips in the same dish it was seen that the strip exposed to radium had been strongly acted upon, whilst the other was only slightly fogged.

It therefore appears that the fluorescence excited in the plate by the radium rays can play only a secondary part in the production of the photographic image.

In conclusion I must express my thanks to Lord Blythswood for enabling me to bring these results before the Society.

Reginald Pecock—a Heretic Bishop of the Fifteenth Century.

By John L. Morison, M.A.

[Read before the Historical and Philological Section, 29th March, 1905.]

In the perennial conflict which youth wages against use and wont there is, for the attacking side, one permanent temper of mind, insolent superiority, and one word to serve at once for creed and battle-cry, "Thou hast made me wiser than all my teachers." The ignorance of the ages, the brilliance of the unassisted intellect, and the indefinitely expansive powers of modern investigation, these are the motives which rule in renaissance movements. It is as with one dominated by this insolence of intellectual reform that I wish to deal with the subject of these notes, for Reginald Pecock is an abnormal instance of the intellectual reformer, and the interest of his career lies in the struggle between the aggressive power of his mind and the dull forces which first hampered and then crushed him.

He was a son of the fifteenth century, born probably just before its start, educated in English ways of learning when these had definitely taken up their last dogged stand for mediævalism; trained in a church which had just succeeded in crushing, to all appearance finally, the influence of the most original of English religious thinkers, Wycliffe; forming his opinions in an England where Henry V. and Beaufort had contrived to recall something of mediæval glory. It is everywhere necessary to bring Pecock and his environment together; for his fortunes depended, above every other consideration, on the *status quo* which he tried to alter.

The church especially demands our attention, for it was Pecock's teacher, his judge, and the cause of his failure to attain the eminence rightly his. His fellow clerics, I have said, had succeeded in driving Wycliffite opinion into apparent insignificance, and deadness of mind, the natural consequence of this conservative triumph, had settled down over the Catholic Church in England. Positive progressive work seemed to have disappeared. Here and there ordinary parsons were doing dull,

honest stop-gap work; great monasteries were maintaining the *status quo* in charity and education, and friars were now and then startling their hearers with blunt evangelic fact, none the less striking for their confusion of it with violent personal opinion. It is true, also, that the century saw much building of churches, and that, down to the Reformation, the laity persevered in their interest in church affairs. But in spite of the fact that human nature still contrived to impart some of its vigour to a corrupt institution, evils were everywhere prevalent too flagrantly to be denied. Records of councils like that of 1414 illustrate these with peculiar emphasis. Abuse of indulgences, abuses in appointments and translations, multiform extortion, nepotism, simony, uncleanness, all these show us that heresy was not the evil most to be dreaded in the fifteenth century church. And what church courts failed to reveal, individuals like Thomas Gascoigne took upon themselves as a prophetic burden. Gascoigne, a gloomy, solid, narrow soul, such as a strict University training tends to breed, conscientious in the subtle way of a pious collegian, desperately in earnest about the abuses which his plain ascetic scholar's mind told him would ruin his beloved church, has left on record judgments and criticisms which did not need Luther's later emphasis to seem impressive. The Jeremiah of the fifteenth century drew up an indictment of the church which carries weight because it does not confine itself to generalities. His stories of simoniac bishops, of fatuous and vitious clerks, and of ecclesiastical sins complicated almost into farce; on the other hand, of faults which found support not in England but at the very papal court itself, give us our best chance of realising the disadvantages which the English churchman of the time had to face.

Yoked with this dreariness in moral things was a greater blankness in intellectual progress. Men in England, especially in religious matters, had practically ceased to think for themselves. No doubt many excellent contributions to mediæval theology were made during the century, but, except in Pecock's case, nothing with the individual or actual note in it. It was the dead season in literature and thought. Lydgate, excellent in dulness, a genius in contriving new forms in which to express the tedium and hopelessness of his mind, was the leader in poetry. Other stammerers in verse and prose strove to teach or amuse in matters of alchemy, or astrology, or third rate morality; and although

Fortescue imparted some of his own sturdy optimism to political literature, he too failed to rise beyond the dulling mist into the region of clear thought. Humphrey of Gloucester certainly comes under another category, for in him one sees glimpses of hope for the future of England. He is the one live influence of the time as he works at connecting Italy and England, at fostering a literary society in his own land, and at stimulating the desire for knowledge in Oxford by repeated gifts of books. It is indeed significant that Pecock should be one of Humphrey's circle, and that the pioneer of the secular Renaissance in England should be patron of the man who gave a first clear statement of what was to be the reformed Anglican stand-point in theology.

Pecock, then, I wish to show as the son of a degenerate century; gathering nothing by way of moral help or elevation from his contemporaries, and creating whatever fresh thought he had, out of a wide reading, a faculty for origination extraordinary in his time, and a self-confidence which never failed except in practical crises. From the first he must have been noticeable for an uneasy and extremely self-conscious intellectual activity which led him to write treatises on every conceivable subject connected with church life, and which must have brought him before the notice of the Duke of Gloucester. But he did not create any particular sensation until, three years after he had been made Bishop of St. Asaph's, he set the ecclesiastical world in a panic by a sermon on the preaching of bishops. First among the many abuses for which the church was attacked, came the easy fashion in which higher churchmen interpreted their responsibilities, and, from first to last, the failure of bishops to teach their flock by word of mouth, found critics within the church. With the self-confidence of a man who knows he has an intellect, the futility of one who has never recognised what truth in practical politics is, and the eagerness of a *novus homo* to support his side, right or wrong, Pecock uninvited and undesired came forward to defend his brethren. To the end of his life he seems never to have recognised that the best defence for an abuse is to say nothing about it, and he never erred so extravagantly, as just at this time. If we may take the "Vindication" as, at worst, a fair record of what he said, he defended his entrance into the discussion on several characteristic grounds. Criticism on bishops, he thought, had become so extreme that, unless something were done, they would lose all reputation. Worse still,

some of the bishops had begun to have scruples, and, in the conflict between material conceptions of duty and the higher spiritual life of leisure, they were developing consciences. And, finally, for the sake of the laity, whom the scandal was fast drawing into wild ways, Pecock felt that he must do something towards intellectual clarification. As bishop, he felt the height of his vocation; as intellectual he despised an intellectual method so rude as preaching (preachers he called clamitatores in pulpitis), having a superfluity of material in his logical armoury he was driven, as clever men will be, to make the worse seem the better cause.

So, at St. Paul's in 1447, Bishop Pecock laid it down as gospel, that bishops were not forced by their position to preach to the people; that they had higher duties; that even if they were bound, they could give themselves liberties here as in other matters; that, often, their residence and preaching in their dioceses would be little short of sinful—with other duties before them. Then, as if to give a final illustration of what his intellect could do, he proceeded to justify the Pope and the English bishops, in practices perilously like simony. Pecock had certainly satisfied himself, as intellectual men will do; but he had, at the same time, roused against himself all that was worst and best in the English church. For the moment he did not suffer. Not even the death of Gloucester stayed his progress, for in 1450 he became bishop of Chichester, and for six years he must have devoted most of his time to the peculiar intellectual exercises so dear to his heart. It was probably in the seven or eight years before 1456 that he organised his great system for the conversion of the Lollards, for his "Repressour" saw the light in 1449, and from his "Book of Faith" we find that he must have spent much time both in writing and arguing on the Lollard question. Meanwhile clouds were gathering. Gloucester was dead, and De la Pole, his rival, but Pecock's supporter, followed quickly. Pecock's friends were falling away, and his little ways were not those by which new friends were to be gained. The man had all the faults of the intellectual character, and his very virtues were dangerous to him. That he was, intellectually, the first man in the country no one could deny, but England, then as now, was able to estimate intellect at its proper low value. Pecock had been ransacking the fields of dialectic, setting things to rights, confuting opponents

by sheer strength of logic, propping up convenient but questionable habits by force of mind; and, all the while, he had forgotten how far the world is controlled by non-intellectual agents. There is something infinitely pathetic in Pecock's confidence in intellectual processes—the more so because he was born an Englishman.

"A sillogisme," he says in his "Book of Faith," "well reulid after the craft in logic, and having two premysses openli trewe and to be grauntid is so strong and so myzti in al the kindis of maters that thouz alle the aungels in hevene wolden seie that this conclusioun were not trewe, yet we schulden leeve the aungels seing and we schulden truste more to the profe of thilke sillogisme than to the contrari seing of all the aungels in hevene."

But intellect of itself need not have caused him trouble; it was the assertiveness of his mind, its refusal to accept the current limitations, and the boundless self-conceit of the man which stung his foes into active and organised opposition. For Pecock was not a modest man. Living in an intellectual world of his own, he came to regard everything from his own point of view. Clever as he was, he began to fancy himself the cleverest of men, and he strewed his writings with traces of his self-sufficiency. Is it a question of Scripture and marriage? He has but to refer readers to one of his own books. "I preie thee, son, seie to me where in Holy Scripture is given the hundrid parti of the teching upon matrimony which I teche in a book made upon matrimony." Or, if prayer be in question, he can assure his readers that his setting of the paternoster is indispensable, with just a a suggestion of improvement on the original. Authorities he holds at little price. Who after all were Jerome and Augustine, who were even Moses and Paul, but mere men; and was not he a man too and a clever man? Authors may be pardoned if they fall in love with their books, they have so few other recreations; but Pecock's love was one which he published far and near. "Ye schule fynde in hem" (his books) he tells the Lollards, "so great witt and leernyng of cristen religioun, that ye schulen hold you bigiled in the trust which ye had before in your other studies and labouris for leernying;" and one of his confuters with a shrewd wit heads a chapter thus:—"Continet duodecimam conclusionem Reginaldi, scilicet; laici tenentur magnificare libros compositos in lingua eorum materna, et praesertim libros quos idem Reginaldus edidit."

This assertiveness of self was but the other side of a daring which, in a stronger man, would have carried its possessor to the highest pinnacle of intellectual fame. This man did care for truth, he did love a cleanly, thorough method of thought, and in an age of mental laxity he set a fair example of both energy and honesty—honesty, that is, if we allow for the sub-refinements of a schoolman's logic. We see him at work, rejecting traditional standards, casting aside old arguments, clearing truth of much hampering rubbish, in short, carrying as far as he had strength that tendency which had, for a century, given Italy a clear lead in European thought and literature. By this strange blending of conceit, brilliant logic, and half honest venturesomeness, Pecock had come to conclusions not at all in accordance with accepted standards. Posing as the defender of the faith, he had often implicitly criticised the faults of the church as fundamentally as he had the heresies of the Lollards. Not all that he ventured on was recognised as dangerous, but, by 1456, when he published the treatise known as "The Book of Faith," he found himself confronted by a band of enemies consisting of nearly all the churchmen with the archbishop at their head, and the scholars of the universities, while a foolishly worded letter to the Mayor of London enabled court enemies to represent him as an enemy to the king. The charges against him were as varied as the number of interests he had offended. Precisians, still sore over the St. Paul's sermon, and seemingly feeling the sting of Pecock's contempt, blamed him for calling preachers "pulpit bawlers," and for allowing that payments to the pope in exchange for ecclesiastical commodities were permissible. Believers in the fathers were offended at his language concerning Jerome and the others. The orthodox knew not what to make of his statements about the creed, that Christ did not descend into hell, and that the apostles did not make the creed called by their name. Still more were they alarmed at his bold defence against the Lollards by exalting reason and the natural law into the place of supreme authority. And, in the end, every interest that depended on conservative and aristocratic aloofness was shocked to find that this bishop had actually advocated the discussion of deep matters in English. Hints were also scattered freely that on the crucial matter of the sacrament of the altar, Pecock was sadly to seek. It was obviously a case where all that remained was to assess the exact amount of sin committed.

It is not necessary here to go over the details of the end. Pecock, without a friend, hated by the church, suspected by the state, maintained a certain dignity up to a point, and then collapsed. On November 28th, 1457, he withdrew from his various positions before his theological examiners, and early next month his humiliation was completed by a public abjuration and the burning of his books. With this terminated Pecock's career. Being an incomplete adventurer he failed to win the martyr's place, and after abjuration he had to accept the new indignities, first of deprivation and then of confinement. In his last days we find him an inmate of Thorney, a monastery in the East Midlands, kept in comparative comfort, but deprived of the one thing he loved better than his own comfort, the weapons for writing and intellectual activity. His library was limited to a breviary, a psalter, a legend book and a Bible; ink was denied him, nor could he obtain paper. The venom of hatred which thus so far reduced him continued strong long after his death. Twenty years after his fall his alma mater took especial care to clear itself from suspicions of Pecockian heresy. King's College, Cambridge, included in its statutes an oath renouncing the works not only of the master heretic, Wycliffe, but also of this well-intentioned failure, Pecock. Suspicion of adherence to his views was the surest sign of a perverted intellect, and we may still gather something of the feeling of the century in such phrases as that of Bury when he suspected that Christ was warning his faithful against Pecock in the words, "abominationem desolationis stantem in loco sancto;" or in the bitter gibes of Gascoigne against this "novellus episcopus."

I have called the man an incomplete adventurer, and so he is with reference to his career, but his writings contain elements of value even to a modern inquirer, and he seems to me to stand as much above Hooker in intellect as Hooker stands above him in character. Let me hint what these elements are in a few closing pages.

Apart from the fact that Pecock's Latin works perished more completely than his English, in the conflagration (since fewer copies of them existed), Pecock ought to be judged mainly along the line of his great endeavour to convert the heretics by rational methods, expressed in the language best suited to the purpose, English. There is a daring of democratic method here far in advance of anything that the Church was to see for years.

Pecock was prepared to stand or fall by a rational appeal to the people, in the people's language. Original as some of his thought is, it is not so boldly original as the scheme thus outlined in the introduction to his "Book of Faith":—"It is not ynouz that the said bokis be writen and made and leid up or rest in the handis of clerkis thouz fame and noise be made greet to the seid lay people of such bokis, and that the bokis schulde opene to hem that thei erren; but the bokis musten be distributid and delid abroad to manye where that nede is trowid that thei be delid." And further "if prelatis and other myzty men of good have greet zele and devocioun unto the hasty turning of the seid erring people; forsothe thei musten at her owne cost do the now seid bokes to be writun in greet multitude and to be wel correctid and thanne after to be sende, and to be govun or lende abroad amonge the seid lay persoonys."

Here at least is honesty and enthusiasm, and the burden of his teaching would have been equally great if Pecock could only have exchanged a little of his conceit for some glimmerings as to the meaning of practical morality. Again and again the reader stands amazed at the keen logical force of his reasoning or at the modernity of his historical attitude until the turning of a few pages brings us back to the misguided sophistical ingenuity with which Pecocks contrives to bolster up false causes. In all his principal books this is a striking feature—as if the author were content to build airy arguments for ever, satisfied if they remained apparently consistent even although their application to practical affairs was hopeless. What could be finer than the argument of his "Repressour" in exaltation of reason. And yet this book, almost deserving to be called great, concludes with one of the most sophistical absurdities ever penned in justification of the most futile of contemporary religious hypocrisies. These are serious flaws, and they are of the essence of the man's mind; yet they must not conceal the value of his positive work.

The "Repressour," taken in its age, seems to me a greater achievement than Hooker's "Ecclesiastical Polity," simply because so much of it is pioneer work, and pioneering carried on under difficulties. To establish the true place of reason in religion involved a careful balancing between church authority on the one hand, and Bibliolatry on the other. It is less than fair to Pecock to say that he did not fail badly. In his great attack on fifteen century Bibliolatry he seized the strategic points with

extraordinary acuteness, and his exposition of Lollard texts might well put to shame modern sons of orthodox exegesis. But, refusing to be restricted to detail, he moved with wonderful ease to the sweeping general position, in authority, that the inner force was always greater than the external expression, and therefore the "law of kind" written in man's soul than "the outward book of parchment." But the "Repressour" with its definition of the place of reason, compared with that of Scripture, is only one part of Pecock's teaching. In the two MSS. with which I deal, and especially in "The Book of Faith" the complementary parts are supplied and material given for a complete judgment of his views.

The "Donet," a manuscript, almost complete, in the Bodleian Library, is, for our purposes, of secondary importance, except in so far as it is an attempt to apply the rational as opposed to the merely traditional method to moral instruction. Throughout its pages Pecock exhibits a disdain of the regular mediæval categories of vices and virtues. It is his wish to substitute a logical order for the schemes known as The Seven Deadly Sins, The Seven Christian Gifts, and all the other old lists. This he evolves in four tables, one, of what he calls "meanal" virtues, the others of "endal" virtues; and so charmed is he with his handiwork that he passes to disparagement of the Ten Commandments, which seem to him lacking in logical force, and without that uniformity and consistency which his Four Tables possess. One would be surer of their virtues if the commendations came from a churchman other than their inventor. Pecock is, as usual, too apt to fancy the mental gymnastics of his reconstruction as the distinguishing symptoms of a brand new inspiration. But even a quiet "Donet" of moral laws, in Pecock's hands, must fly at higher game than the Ten Commandments. For in it we have the fullest statement existing of his views on the creed; indeed this is the volume which contains that English version of the creed which was Pecock's greatest offence against ecclesiastical decency. Like most men who venture away from the beaten track, Pecock had his pet eccentricities or heresies, and two of these were concerned with the Apostles' creed. One raises the question of Christ's descent into hell; of which it is sufficient to say that the "Donet" version omits the article altogether. The other deals with belief in the Holy Catholic church, and here Pecock has his clear cut phrase, "I believe his

holy and universal or general church to be." He had his own peculiar opinions about the fallibility or infallibility of the church, but he was not willing to give the game away so completely as to say that he believed in the Holy Catholic church, if that meant utter submission.

The "Donet" is interesting as a sectional attempt at intellectual reconstruction, but the "Book of Faith," the volume which probably brought the heresy hunt to its consummation, faces up questions of the highest import, and although the manuscript breaks off *in mediis rebus,* it contains sufficient to entitle it to a place first among fifteenth century English theological treatises. It is hampered by the same old unattractiveness of style and logic, and misdirected often by Pecock's most aggravatingly sophistical manner, but in three or four passages it relates itself, not so much to Hooker's work as to the more serious productions of the scientific or agnostic mind. The book is in form a dialogue between a father and a son, and the subject is the nature of faith and the problem of authority. Since, as his own words have it, "all goddis creatures musten nedis obeie to doom of resoun." His faith, to be discussed, must be somehow or other rational. He admits, of course, what we would call truths of revelation, facts which we cannot find out by natural wit; of these he instances "that a mayde bare a child and that thilke child which Marie the mayde bare was and is man and God." But here his admissions end. Truth, even revealed truth, in Pecock's estimation must submit itself to the human reason to be tested by the syllogism, and so, with a daring which reminds one of Milton at his boldest he prays Christ to ordain that "the law and the feith which the Chirche at any time kepith, be receyved and admitted to fall under this examinacioun whether it be the same verri feith which the apostles' taughten, or no." "It is a vilonye," he indignantly exclaims, "a vilonye putten to Crist that he schulde zeve such a feith to his peple, and into which feith he wolde his peple turne all other peple, and zitt he wolde not allowe his feith to be at the ful tried." Nor is this mere talk, for like Milton, he sees the utilitarian argument for free inquiry. "If clerkis take not hede how and wherebi the articlis of our cristen faith owen to be groundid and provid and defendid, such tyme may come in which adversaries schulen fynde the postis and the pilers of our feith so unleernyd and nakid for to meyntene and defende oure feith that the adversaries bi

her greet evydencis to be maad withynne the boondis of the kinde perteynyng to feith, schulen perverte myche multitude from feith."

Such an aggressively rational faith must naturally raise the question as to where that church comes in; the church here being rather the representative of tradition and the minor sorts of irrational revelation. Faith, and the church, Pecock held, were the two necessary sides of one great fact; but of the two, faith based on reason must hold its own. Doubtless the church may add to faith truths attested by miracles, but what miracle will pass Pecock's text; a miracle "agens which no man kan notabili repugne that it is not myracle doon by God."

If then the church owns a faith rational and experimental, Pecock is prepared to be asked whether individuals may correct the church where it errs. Error and its possibility he admits, but visions of stout bricklayers and tailors wresting God's Word to suit themselves doubtless passed before him, and he ends the first part of the book by allowing criticism of the church, provided it be successful, and that the success be acknowledged by the church itself. Failure or only partial success means damnation; a pretty dilemma for the honest man. "Into tyme zoure motives be examinid togidere with the motives of the chirche, holde ze never you to have better evidence for youre side than the chirche hath for her side and holde ye not yourself to be out of state of damnacioun."

Time permits me merely to summarise the conclusion of the book, where passing from faith itself Pecock discusses the relative importance to faith, of the Bible and the church. It may surprise those who know only the "Repressour" to find that Pecock decides in favour of the scriptures. Tradition, he says, and sources verbal and oral are useless in great matters. "O my son, if thou woldest take hede how a tale or a tiding bi the tyme that it hath runne thorough four or five mennys' mouthis taketh pacchis and cloutis and is chaungid in dyvers parties and turned into lesinges, and al for defaute of therof the writing, . . . thou schuldest ful soone and ful sikerli deeme and so schulde ech wel avisid man deeme that the long tale of the gospels mizte never bi eny long tyme bi treuli and after oon maner toolde." In the spirit and with a curious anticipation of modern criticism of Genesis, Pecock refuses to believe that Genesis was an inspiration given to Moses. He traces the connection in literature from Adam through

Enoch, Methuselah, and the others, to Moses, and converts Moses from an inspired prophet into a sort of literary hack. Curiously enough Pecock and a certain Anglican canon of to-day might well shake hands across the centuries on this point.

Inspired by a spirit of this sort it was hardly likely that Pecock would grant many concessions even to that church whose son he owned himself. Let it obtrude its miracles if it will, but, in notable words, "To privey myraclis we schulde not renne for to defende our opinioun or oure answere bi hem without that sufficient evydence therto serveth. For ellis there myzte noon opinioun be overcome bi strengthe of argument how false ever the opinioun were." And again, when with grudging our author has allowed his church to infringe on faith and scripture so far as to institute holidays and saints, not mentioned in the Bible, he must yet stultify his miserable concession in these words, which surely Mr Huxley himself would not have disapproved:—"Thomas of Cantilbiri is a seint; Joon of Bridlington is a seint, . . . and so foorth of othere whos lyvyng and for whom the myraclis doon bin well examyned and tried bi witnessis sworne. Notwithstonding that, pretense myracles and pretense inspiraciouns and pretense appeerings of God and of aungels withynne forth and without forth, and legends or lyves of seyntis and othere stories which ben writen and hadde in fame, ben ful slider and unsure groundis for to grounde upon hem feith (that is to say a treuthe passing nature and revelid by God) without passing great trial of hem."

Near the imperfect end our bishop tends toward his old troubles over the creed once more; but already we have had sufficient grounds for setting this fifteenth century heretic (for he was a heretic) high in the ranks of the intellectual innovators of English history. The tantalising thing is that his career should have been so imperfect, and its end so comparatively base. The irony of fate will have it that this man who worked out for himself a theory of rational knowledge, who could discriminate between the false and the true in evidence, who, while a churchman, could set the church in its right place of secondary authority, and who combating with Bibliolaters, could yet see the greatness of Sacred Writ, and interpret it with a correctness unknown to its idolaters, should pass out of history basely consenting to errors which the fundamentals of his writings went to confute; abandoning the fruits of a life's hard work and substitut-

ing for them the dogmas of a doggerel verse which tradition says he latterly would repeat.

> "Wit hath wonder that reason cannot scan
> How a mother is maid and God is man,
> Leave reason, believe the wonder,
> Belief hath mastery, and reason is under."

Reason indeed was under; yet how much must we blame the age; how little the man. Courage is not except in great and venturesome ages the virtue of the thinker; and the habits of the study do not conduce to steadfastness at the stake. And Pecock was not the student with an admiring student audience. He was an innovator without a single backer of note; a poor, feeble mental force, mind without its full share of conscience and will power faced by the honest bigotry, the unreasoning conservatism, the whole organised force of intellectual and moral sloth in England. Remember, too, that the State, in so far as it is counted, was on the other side, and that hints of treason embittered Pecock's position. In the cold bleakness of the man's isolation, with not another living Englishman to look on him with sympathy; with not another Englishman competent to side with him nearer than half a century off, it was natural that Pecock should have ruined for himself the work of his life. Few of us are fit for martyrdom except in our comfortable fireside moments, and so we may let this extraordinary intellectual portent pass with gentle criticism; smiling at his conscious self important ways; angry at his sophisms; honestly warmed by his devotions and enthusiasm, such as they were.

CENTENARY LECTURES, NO. VIII.

The evolution of Zoological Science during the Nineteenth Century. By J. GRAHAM KERR, Professor of Zoology in the University of Glasgow.

[Prepared by request of the Council, and delivered before the Society 8th March, 1905.]

THE Zoological Science of to-day may almost be called a child of the Nineteenth Century: to write its history during that century would be to write the history of the whole Science as we know it now. Such a compilation would be the work of a lifetime and would need for its accommodation not a few pages, but a row of bulky volumes. In this evening's lecture I propose not to attempt a historical resumé, but merely to sketch the main lines along which certain aspects of Zoology have developed or evolved during the Century under consideration.

ZOOLOGY IN THE FIRST DECADES OF THE CENTURY.

If we study the state of Zoological Science in the earlier part of last century we are struck alike by the splendid enthusiasm of its workers in seeking after facts and by the absence of any common inspiring idea. It was a period especially of detailed research. Our Faunistic knowledge was rapidly increasing. Scientific voyages were being carried out by Government ships —the French Astrolabe and Bonite, the Russian Rurik, the Austrian Novara, our own Beagle and Rattlesnake. Tropical lands were being actively explored by such travellers as Azara, Spix and Martius, Castelnau. The vast collections made were brought home to Europe, were worked out and helped to form the frame-work of the Zoological science of to-day. At home the local fauna found various enthusiastic investigators such as Fleming, Jenyns, Johnston, Forbes, Bell, Yarrell.

With the great increase in the numbers of known animal forms, there gradually came into being the system of classification. Cuvier recognised the division of animals into Vertebrates and Invertebrates, while amongst the latter he distinguished four

types, Mollusca, Articulata, Zoophytes, and Echinoderms. Cuvier's ideas of classification are permeated with the idea of fixity of type and sacredness of species. The successive Faunas of the various Geological periods he explained as due to a series of cataclysms by which all life was exterminated, each one followed by a new Creative Act.

Monet, afterwards Chevalier de Lamarck, made a great step forwards when he recognised that the various types as well as subdivisions marked successive grades of increasing complexity. His main grouping of animals into Apathetic — including Infusoria, Polyps, Worms and Echinoderms, Sensitive—the higher Invertebrates, and Intelligent—including Vertebrates, appears perhaps crude to us now, but we must bear in mind that it expresses the enormous advance that I have mentioned—the realisation that the scheme of natural classification does express stages in increasing complexity or degree of development—stages in evolutionary progress. And in the details of his system Lamarck introduced various improvements which are still recognised *e.g.*, the separating of Annelida as a main group by itself, as also Crustacea, Arachnida, and Insecta amongst the Arthropods. In the hands of H. Milne-Edwards, Siebold Leuckart and others, the main classification assumed in at least its general features the form which it has still. And during these decades there was a magnificent mass of work accomplished on the anatomy of various special forms of animal life work handed down to us in the splendid monographs of Cuvier, Johannes Müller, Owen and other workers.

Apart from the great advance in faunistic knowledge, the chief value of the work of the period is anatomical rather than morphological, *i.e.*, it lies rather in the accurate descriptions of structure than in the exposition of the bearings of structure upon general ideas. Not that such ideas are absent. Hardly any worker has been more fertile in general ideas than Oken for example. But his ideas are in the nature of wild speculations. Instead of pursuing the scientific method of induction from bodies of facts he arrived at the idea, and then sought facts to support it, and was often, no doubt unconsciously, biased by his preconceived ideas, not merely in his description but in his observation. In the preface to his "Naturphilosophie" he refers to his famous theory of the skull thus: "I have shown that the head itself is none other than a vertebral column, and that it consists of four

Vertebræ, which I have respectively named Auditory, Maxillary or Lingual, Ocular and Nasal vertebræ. I have also pointed out that the maxillæ are nothing but repetitions of arms and feet, the teeth being their nails."

But all the general ideas of these decades were not so fantastic. For to that earlier half of the century we owe the development of a general idea which has had the greatest influence on the advancement of Biological Science—the Cell Theory of Schwann and Schleiden. This theory emphasised the importance of the cell —a nucleated mass of protoplasm—as the unit of structure, out of one or more of which all living bodies are built up. It has only been in recent years—in the closing years of the century—that Zoologists have begun to suspect that there has been perhaps too great a tendency to regard cellular structure as fundamental. Whether or not this has been the case, the Cell Theory regarded as a working hypothesis has been extraordinarily fertile, and has had the greatest influence, not merely on Morphology, but also on Physiology, and Pathology.

Taking a broad survey, however, of the progress of Zoology during the first decades, we may say that it is characterised by the more or less aimless accumulation of detailed knowledge. Individual men worked enthusiastically at the hunt for new facts, as to-day individuals hunt after new stamps, or new articles of any kind which they happen to collect. There was no great general idea which stirred men's minds and caused wide spread enthusiasm for research to test its truth. During the fifth and sixth decades of the century work was being done in a quiet Kentish workshop which was destined to change all this.

Charles Darwin had left Edinburgh where he had begun the study of medicine, had gone to Christ's College, Cambridge, had, after some thoughts of going into the Church, taken a poll or ordinary degree, and, being interested in Natural History, was recommended by Henslow for the post of Naturalist to accompany Fitzroy on a surveying expedition on H.M.S. "Beagle." After returning from his five year's voyage Darwin attracted attention as the writer of "The Voyage of the Beagle," as the author of the admirable report on the geological results of that voyage, as the framer of an ingenious hypothesis to account for the origin of Coral Islands, and finally by his authorship of a most admirable monograph on the Cirripede crustaceans. But his work, which was destined to revolutionise Biological Science and to have the

most far-reaching influence upon Science and Philosophy generally, was that in which he developed his theory of Evolution through Natural Selection. Based upon an extraordinarily thorough analysis of the facts of Heredity and Variation already known, together with a wide range of personal observation and experiment, the theory was given a general treatment in the Origin of Species published in 1859, while succeeding years saw a series of other volumes, each dealing with some portion of the foundations upon which the Theory was built.

THE EVIDENCES FOR EVOLUTION.

It will probably be best if before dealing with the influence upon Zoology of the development of this great idea I say something as to why now as in the closing years of the Nineteenth Century Biologists universally accept Evolution as their working hypothesis. There are four main categories of facts which force Biologists to do so.

(1) THE FACT OF EVOLUTION IN THE INDIVIDUAL.

We know as an observed fact that evolution does take place in Nature—evolution of the individual. When we study the life history of almost any one of the more complicated animals, we find that it begins its existence as what is termed a Zygote—as a simple nucleated cell. If this Zygote lived free in Nature and remained a Zygote, we should call it a Protozoon—a member of the lowest of the great branches of the animal kingdom. As a matter of fact, however, it divides up and forms a mass composed of a number of cells and in many cases these cells assume the form of a double-walled cup. If this stage lived free in Nature we should recognise it at once as a member of that one of the great groups which comes next to the Protozoa in simplicity—the Coelenterata—the group containing sea anemones and allied forms. The only character, in fact, which prevents us from calling this so-called "gastrula" stage a Coelenterate, is the fact that it does not remain a gastrula, but goes on to become something else.

Again, if we examine a series of embryos of a bird or mammal—anyone of the higher Vertebrates—we find that at a certain stage in its development it shows on the sides of its neck a series of gill clefts like those of a fish, not only so, but the great arteries are arranged not as they are in the adult bird or mammal but in the way they are in a fish, adapted for the conveyance of the blood

stream past the walls of these clefts. Instead of the highly complicated vertebral column of the adult, we find a simple elastic rod identical with what we find in the most lowly organised fishes. Instead of the wing or hand or foot we find a simple paddle-like structure. If this embryo were found living free in Nature even the elementary student would recognise it as a *fish*.

The individual then does undergo a process of evolution—from the apparently simple to the apparently complex—and frequently as in the cases I have mentioned, stages in this process correspond with conditions found in adult creatures of more lowly organised groups. The ordinary characteristic features of the individual are, of course, due to inheritance. Is it not reasonable to suppose that this remarkable evolution of the individual is also there because it is inherited—because its ancestors in the past have shown corresponding stages in the course of a slow evolutionary change?

It is not merely the individual as a whole which shows this process of evolution. The same thing is seen even in a more pronounced form in the formation of the various organs of the individual. As an example, I may take the development of the breathing organs in the Scorpion. These consist of four pairs of lungs, each lung consisting of a small chamber opening to the exterior by a slit-like aperture, and possessing in its interior a remarkable series of thin leaf-like lamellæ lying one over the other like the leaves of a book and richly supplied with blood—these lamellæ serving for the actual respiratory process. Now, when we study the embryology of the Scorpion, we find that these breathing organs undergo a remarkable series of developmental changes. In an early stage we find in place of each lung a rudimentary leg—in series with the ordinary legs of the creature—and from the hinder face of this leg there arise a number of small projections. As the embryo goes on with its development this leg-like structure comes to project less and less above the general surface until at last it is flush with the surface and the projections on its hinder face are contained in a little depression of the skin behind the appendage. Finally, this depression, becoming deeper and nearly shut off from the exterior, forms the cavity of the lung, and the projections from its wall form the respiratory lamellæ. Now, why should the lung of the Scorpion arise in this remarkable fashion? The answer is found by an examination of such a relative of the Scorpion as the King Crab

(*Limulus*), where we find the breathing organs consist of book-like arrangements of respiratory lamellæ, not contained in a cavity, but projecting freely from the hinder aspect of certain of the limbs, so as to come into free relation with the watery medium in which the creature lives. We now see that the breathing organ of the Scorpion in its development merely passes through a condition in which it persists throughout life in aquatic relatives of the creature. Is it not reasonable to see in this an inheritance from aquatic ancestral forms from which Scorpions and King Crabs alike are derived?

(2) THE EVIDENCE OF PALÆONTOLOGY.

But if this be a correct explanation of the cause of individual evolution, ought we not to find traces of the evolutionary process in the records of the rocks as displayed to us by palæontology? We must guard ourselves against expecting too much in this way. We must bear in mind the extreme imperfection of the palæontological record. We must remember that only a small proportion of animals die in circumstances in which they are likely to become enclosed in rockforming deposits. Again, how perishable are most of the parts of the body, or indeed the whole body in many cases, even when appropriate entombment takes place. And finally and most important, we must bear in mind the fact of the extraordinary imperfection which must for ever characterise our knowledge of palæontology. To have a complete knowledge of this science we should have to make a complete investigation of every fragmentary rock which has been laid down since the dawn of life upon the earth. As a matter of fact, the probabilities are that a large proportion of these rocks have long ago passed out of existence in the course of Geological changes, while of those that remain the only knowledge we can gain is that afforded to us by the relatively insignificant scratchings of the surface which are afforded by quarrying and mining operation.

When we bear these considerations in mind we cannot but marvel at the value of the evidence which this infant science of palæontology has already given to us. It has given us wonderful links which connect up some of the main groups. The Reptiles as we trace them back in time are seen to grade into forms which are practically Amphibians: the birds – these most specialised of existing Vertebrates—are linked up by *Archæopteryx* to the Reptiles. Then in certain deposits we find twigs of the evolutionary tree almost intact. I may draw your attention to two

such. The first illustrates a bit of the evolutionary history of the genus *Paludina* or *Vivipara* as shown by the fossils in a series of Pliocene beds marking the site of great lakes which apparently at that time covered a great part of the Balkan peninsula region. In this case the lowest beds show species of *Paludina* of more or less typical character. In the succeeding beds, however, the predominant forms show a gradual change until in the uppermost beds they are of the type which is now called *Tulotoma*, a genus which has disappeared from Europe but survives in North America.

The other case to which I would direct your attention is that of the ancestry of the Horse, one of the most highly specialised of present-day Mammals. The researches of the American Palæontologists have shown how, as we proceed backwards in Geological time, the highly specialised horses of to-day were represented by less and less specialised forms until eventually in the Lower Eocene deposits they are represented by forms showing relatively insignificant divergence from the ordinary Mammalian type and no larger than a Whippet dog.

(3) EVIDENCE OF COMPARATIVE ANATOMY.

In the facts of comparative anatomy—that part of Zoology which deals with adult animals, we again find at every turn things which are as easily explained by the Hypothesis of Evolution as they appear inexplicable without it. How unlike to one another are such mammalian organs as the forefoot of a horse, the wing of a bat, the flipper of a whale, the hand of a man! And yet by a comparative anatomical study of these organs we are shown that this unlikeness is quite superficial, that these apparently unlike structures are all really modifications of a primitive type of forelimb such as still persists in such comparatively lowly organised Vertebrates as some of the Reptiles. How can we explain this but by the hypothesis that they are all derived from a common ancestral form.

Again, how like to one another appear the eye of a cuttlefish and the eye of a vertebrate. Comparative Anatomy aided by Embryology shews us that here the resemblance is quite superficial, that in intimate structure and in development the two organs shew fundamental differences. How should we explain this fundamental difference between organs apparently alike, and which perform, so far as we know, exactly the same function, save by the hypothesis that they have been developed from ancestral organs which were originally unlike?

Again, if instead of considering special organs we take a general view of the facts of Comparative Anatomy we find that they lead to a "natural classification" of animals which is at once understandable on the hypothesis of genetic affinity due to Evolution but upon no other, the various forms when arranged according to likeness and unlikeness falling into just such groups as would be produced by closer or less close blood relationships.

(4) EVIDENCE OF GEOGRAPHICAL DISTRIBUTION.

Equally striking are the phenomena of distribution of life over the earth's surface. *A priori* we should expect this to depend entirely on physical conditions. The degree of likeness between the fauna of two localities should be proportional to the degree of resemblance between their physical conditions. If we choose two spots on the earth's surface at which these conditions approach identity we should expect the same to hold with regard to their fauna. As a matter of fact we find that this does not hold except as regards superficial characters which are probably in direct relation to environment. When we study the more deeply seated characters we find that the resemblance between these is related much more closely to the freedom of access between one locality and the other. In the case of two portions of tropical ocean where the conditions are very similar, but which are separated by a narrow strip of land of considerable geological age, there is found to exist deep seated difference between the two faunas. And similarly with islands separated from the mainland by deep and presumably ancient oceanic barriers. The resemblances and differences on the other hand are exactly such as we should expect on the hypothesis of a process of evolution and gradual spreading of forms of life over the earth's surface.

Biologists then hold that any one of these categories of evidence which I have cited— and I might have spent the whole evening giving you examples illustrating them—each of these categories is in itself sufficient to render it highly probable that an evolutionary process has been at work, but the agreement between the various categories renders it absolutely impossible to avoid being convinced of the certainty of this process.

THE CAUSES OF EVOLUTIONARY CHANGE.

The question then arises as to the immediate cause of such an evolutionary process. This cause might be supernatural or natural. The former, of course, might provide a wholly adequate explanation. Experience teaches us, however, that with increase of knowledge

the outer crust of the natural is shown to be thicker and thicker, while the supposed core of the supernatural seems to retreat farther and farther beneath the surface. A savage sees in such phenomena as eclipses, earthquakes, storms, disease, the immediate workings of supernatural beings : the advance of science shows on the other hand that such phenomena have their immediate cause not in the supernatural but in the natural. It is then our duty to enquire whether there is any natural process at work which is competent to furnish an immediate cause for this evolution which has unquestionably been going on.

EVOLUTION THROUGH NATURAL SELECTION.

Now it is in the demonstration of the existence of just such a process at work in nature, and of its competence to produce evolutionary change, that by far the greatest advance in Zoological Science during the nineteenth century consisted. I need hardly say that this *demonstration* was due to Charles Darwin, though the existence and importance of this same process was emphasised synchronously by Wallace.

This great factor in evolutionary change is what Darwin called "Natural Selection," or as Spencer called it the "survival of the fittest.

The materials on which Natural Selection works are provided by Heredity and Variation; Heredity by which the characters of the parent reappear in the offspring, Variation by which the sum of these characters never appears *exactly* as in the parents, but always with slight differences. The foundations of the Theory of Natural Selection are laid to a great extent upon the all pervading phenomenon of Adaptation to the environment in which the animal lives. The completeness and precision of this adaptation is simply amazing. It appears in its more obvious forms in such external features as protective coloration, more obscurely in adaptations of life history to environment. Protective coloration may almost be said to be universal amongst the higher animals living wild in nature. Even pronounced markings which in a museum make an animal appear extremely conspicuous, frequently have for their function in nature the breaking up of the continuous colour surface and the continuous outlines which are so apt to betray the presence of the creature. Amongst the South American cats the two largest are the Jaguar and the Puma. The colourings of these creatures so different are yet both adaptive: the Jaguar

as it steals along in the speckly light by the bank of the forest stream and the Puma amidst the reddish grass tops of the open savannah are alike rendered inconspicuous by their colouring. Even the dark coppery skin of the Indian is highly protective. The explorer will at times become suddenly aware that the forest margin, it may be less than a hundred yards off, is alive with Indians, motionless as statues, and rendered almost invisible by their colouring. Even such a feature of coloration as the dark along the back and the white on the under surface, so frequently seen in Mammals and Birds, has been shewn by Thayer to be a beautiful adaptation for the purpose of counteracting the graduated intensity of the light which falls on the creature and so rendering it inconspicuous. Of course many cases of protective resemblance are much more obvious: I may instance the case of the wonderful fauna which is found living amongst the lichen-clad terminal twigs of the trees in tropical forests and which has not yet been properly investigated. One finds there Lizards, Snakes, Frogs, Beetles, Homopterous insects, Locusts, Phasmids, Mantises, Spiders, all shewing the most marvellous resemblance to the lichens amongst which they live, a resemblance so remarkably accurate that on looking at the debris swept from the forest twigs one imagines for a time that one is looking simply at a mass of lichens until a stray movement betrays the animal nature of a considerable proportion of the mass.

Perhaps the most impressive examples of protective resemblance are found in cases where the animal resembles not some inanimate or vegetable part of its environment, but some other animal. Such cases of mimicry are particularly well seen in various tropical butterflies, where certain species belonging to edible groups show, especially in the female, such an extraordinary resemblance to species belonging to inedible groups as to deceive even a skilled observer. Diagrams are shown illustrating some particularly remarkable cases of such mimicry.

From amongst types of adaptation of a less superficial kind I may cite such cases as the life history of two forms of parasitic worms of the genus *Filaria*. In the first of these *Filaria bancrofti* the worms—of microscopic size—are found in the blood of the natives of various warm regions of the world: in some places nearly every individual being infected. If blood taken from skin punctures be examined the worms are found to show a remarkable diurnal periodicity. During the middle of the day there may

be none visible, about sunset they begin to appear and, becoming more and more numerous, they reach a maximum about midnight when there may be hundreds in a single drop of blood. As the night wears on they become less abundant and soon after sunrise they have completely vanished. We now know that these worms are the young belonging to parent worms which inhabit the lymph spaces, where the young are born and whence they pass into the blood stream. They come to exist there in prodigious numbers, and their periodicity in the peripheral blood is found to be due to their performing a diurnal migration. During the day they pass into the deep vessels, particularly those of the lung; during the night they migrate to the vessels of the skin. Now this very remarkable migration turns out to be an exquisite adaptation to the habits of the second host. The young Filarias go on with their further development *only* if they are taken into the body of a particular species of mosquito, and that particular species happens to be one which flies and feeds during the night. In the case of another but allied species of blood-inhabiting Filaria the intermediate host is a day-flying mosquito and here the migration to the skin takes place during the day time instead of during the night.

In the Guinea worm *Filaria medinensis* we find again beautiful adaptive features. The well known Guinea worm is the adult female, the male being a much smaller creature which apparently remains attached to the female for some time and then drops off and dies. When the embryos in her enormous uterine tube are mature the Guinea worm works her way downwards in the body of the patient, the head appearing at the surface, frequently in the region of the ankle or lower part of the leg. If some cold water is poured over this spot a drop of milky fluid immediately appears and microscopic examination proves the milkiness to be due to myriads of young Filarias which the mother has put forth. This remarkable reaction on the part of the mother worm is now known to be due to the fact that the intermediate host is in this case the little fresh water crustacean *Cyclops*. The bringing forth of the young in reaction to the contact with cold water happens in nature when the native wades through a swamp or pool in which *Cyclops* nearly always abounds.

I have quoted these examples to illustrate what is meant by the phrase Adaptation. Observation of nature in the field shows that in Adaptation we have one of the most nearly all-pervading principles of animal life. The more deeply researches are

carried into the relations between organisms and environment the more it is found that characters at first sight meaningless turn out to be really adaptive in character. Other characters not adaptive in themselves may be linked up to directly adaptive ones by that mysterious principle correlation. So general indeed is adaptation that an adequate explanation of the evolution of adaptive features would obviously go a long way towards the explanation of evolution in general.

Charles Darwin's theory of evolution by means of Natural Selection provided such an explanation. The fact of Natural Selection depends in the first place on the fact that any species of animal tends to increase enormously in numbers, and in the second place upon the fact that owing to environmental limitations, and in spite of this tendency the number of individuals remains as a rule roughly constant. This means an enormous death rate. For example, certain fishes produce very many thousands or even in some cases millions of eggs. Yet their numbers show no sensible increase. In other words each pair of fishes is replaced in the next generation by a single pair. If only *one* thousand young are produced by the particular species it is obvious that the two which on the average survive to the term of their natural life are represented by 998 which die prematurely. Darwin drew attention to what seems a very obvious fact—that this death rate is not absolutely at random. Individuals, as we have seen, all vary somewhat from the mean character of the species, and the character of the species shows well-marked adaptation to the environment. Of the varying individuals some will necessarily vary in the direction of better adaptation—of being more fitted to survive, others in the direction of less perfect adaptation—of less fitness to survive. The latter will be handicapped as regards the former, they will be more liable to natural dangers, they will die sooner, they will leave fewer descendents. The former on the other hand will have natural advantages, they will be less liable to natural dangers, they will on the average survive longer and leave more descendents. The same will go on in the descendants, the tendency to vary towards or from better adaptation will be handed down, and nature will go on gradually selecting the strains showing favourable tendencies, allowing them to survive and reproduce, and all the while eliminating those strains tending towards unfavourable variation. It is obvious that in this way there *must* be produced a gradual change towards better and

better adaptation, in other words, an evolutionary process must be brought about.

That a process of Natural Selection is at work and does produce a certain amount of evolutionary change is probably now admitted by all trained Biologists. Some there are, however, who doubt whether it is really one of the chief factors at work. Such doubts are particularly apt to come from the purely Museum or Laboratory Naturalist. To such it may be recommended to spend a few months or better years in some wild part of the Tropics, away from the artificial aids of civilisation, and the experience gained will drive into the mind the meaning of the terms Adaptation and Struggle for Existence in a way that cannot be otherwise realised. Exquisite adaptation will be seen all around and Nature will be seen at work pitilessly working still onwards towards perfection, mercilessly weeding out the individuals who have become slightly unfit. It seems incredible that anyone after such an experience can doubt that there in the Tropics is Nature's great workshop for the production of new forms of life, and that Natural Selection is the great mechanism, and Variation the raw material, which is being made use of..

An obvious character of evolution by Natural Selection must be its extreme slowness. And those who are not Biologists nor as a rule Geologists have seized upon this and raised the objection that Time does not allow of Evolution having been so brought about. To this the Biologist replies that he knows as yet of no limit marking off Biological time from Eternity. Mathematical calculations which seem to impose a limit are, and must always be, subject to the absolutely fatal objection that they are based upon data which may be incomplete in the most fundamental respects. As an illustration may be cited the recent discovery of Radio-activity which shakes to their foundations all calculations of the extent of Biological Time based on the supposed rate of cooling of the Earth.

I have endeavoured to give some idea of what is meant by such terms as Evolution, Natural Selection, and Adaptation, and why it is that Biologists are driven to accept the fact of Evolution, and that a large proportion of them consider Natural Selection a sufficiently potent cause to have played a great part in the Evolution of the various forms of Animal life.

These ideas were first driven into the minds of Biologists by the publication of "The Origin of Species." By far the most

important influence upon Zoological progress lay in the enforcement of the idea of Evolution. The idea itself was of course a most ancient one, but it was Darwin who demonstrated its truth and who at the same time enchained men's interest by showing Natural Selection to be an active evolution-producing cause. Perhaps the greatest service rendered to Zoology by the Theory of Natural Selection has been help towards the acceptance of the Evolution idea. Whether, as many believe, Natural Selection is actually one of the most important of the doubtless numerous factors which conspire to produce evolutionary change, or whether it is merely a subsidiary factor, is a question of minor importance as compared with the main question of Evolution or no Evolution.

EFFECTS OF THE ACCEPTANCE OF THE EVOLUTION IDEA.

In the first place a working hypothesis, the Evolution idea before long became an accepted Theory. As an accepted theory it brought about the great evolutionary step of the science itself from the condition of an indefinite incoherent aggregration of facts to an ordered coherent whole, but it is of course in its former aspect as a working hypothesis that Evolution has had its greatest influence in stimulating detailed research.

The fascinating character of the evolutionary idea caused a very widely spread interest in Zoological problems, and hence a great increase in the number of researchers. The classification of animals, formerly a dead formula, now became a living reality, for it was realised that the construction of a natural scheme of classification really meant the construction of the genealogical tree of the various forms of life. Interest in Comparative Anatomy was stimulated—in the details of structure on which classification rests: interest in Palæontology—for that might provide bits of the genealogical tree ready put together: interest in faunistic work—for it was realised that the geographical distribution of animal forms was a function of their evolutionary history. Haeckel, in Germany, directed special attention to the study of Comparative Embryology. He formulated definitely the famous Biogenetic Law—according to which—Ontogeny, the development of the individual, is a shortened up recapitulation of the development of the race—a law which, though we now appreciate more thoroughly than Haeckel did the potent

disturbances which the ontogenetic record has been subjected to —still is an important principle of Embryology.

And, as is natural, much study has been devoted to the fundamental phenomena on which evolution rests—the phenomena of Heredity and Variation. The phenomena themselves have been studied. They have been studied from two different points of view. Francis Galton laid the foundation of a statistical investigation of Heredity. In man he collected information regarding the physical characters of the parents, grandparents, and so on, of large numbers of individual human beings: again he studied the individuals in the breed of Basset hounds raised by Sir E. Millais, full particulars of which had been placed on record. As a result of his investigations he formulated the Law of Ancestral Inheritance according to which the parents contribute together $\frac{1}{2}$, the grandparents together $\frac{1}{4}$, the great grandparents together $\frac{1}{8}$—and so on—of the total characters of the individual. According to this the inherited characters of the individual are derived from the whole series of ancestors.

Another line of investigation, that dealing with the phenomena of heredity as seen in experimental breeding from a pair of individuals differing in some isolated well pronounced character, was inaugurated by Mendel in the sixties, but curiously enough, his work remained practically unknown and without influence on the general progress of biological investigation until about the close of the century. Perhaps the most important result obtained in Mendel's experiments, which were carried out on flowering plants, was the demonstration that when two mutually exclusive characters are possessed by the male and female parent, they are in many cases transmitted *pure* to the descendents, the proportion of individuals showing each character being a definite one in each generation. It is clear to us now that this Mendelian inheritance must be of great importance in evolution through Natural Selection by causing favourable variations to be handed down to large numbers of individuals and so counteracting the swamping effects of intercrossing.

VARIATION.

In regard to variation, a great step in advance was made by Weismann when he proved the hollowness of the universally-made assumption of the inheritance of acquired characters and established the position still held by the Biologist of to-day that

the evidence for the transmission to offspring of characters acquired during the life-time of the parent is absolutely insufficient to justify our making any such assumption. Of the general importance of this position in relation to such problems as those of Sociology I need not speak: in relation to the problems of Biology in the strict sense its great importance lies in the fact that it must constitute a considerable hindrance to evolutionary changes. Another important advance in the study of variation has lain in the gradually increasing recognition of the necessity of precise methods and precise terminology in such investigations. This has been mainly due to the efforts of the Biometric School, *e.g.*, Galton, Pearson, Weldon, who have devoted special attention to variations in dimensions, *i.e.*, in characters which can be measured, and whose variations can be investigated by the precise methods of mathematics. The study of such variations brings out the fact that ordinarily they are grouped round the mean dimension in such a way as to fall into the curve known as the curve of frequency of error. At times the curve is found to be rendered skew by some disturbing factor; at others the curve is found to present two apices indicating two positions of relative stability about which variation is taking place, giving us a hint that here we may have a species in course of dividing into two; or we may find that the curve, in early life symmetrical, becomes more and more lopsided as life goes on, indicating a selective death-rate, in other words demonstrating natural selection at work.

The study of the gross phenomena of Heredity and Variation has further directed attention to the minute phenomena of Reproduction upon which these must rest.

MECHANISM OF HEREDITY AND GENETIC VARIATION.

The offspring of two parents are characterised by their, on a rough average, similar resemblance to the two parents. In many forms the early part of development takes place quite away from both parents and hereditary tendencies must therefore be present in the Zygote or fertilized egg. They must be brought together by the union of the two germ cells which unite to form the Zygote. This being so it becomes of the greatest importance to study down to the minutest observable detail the phenomena attending this fusion—this process of fertilization. It was not

till about the beginning of the last quarter of the century that the labours of Auerbach and Bütschli, and particularly of O. Hertwig and Fol, followed a little later by Boveri and van Beneden, laid a firm foundation for our present day knowledge of the process and a long series of refined observations by these and other distinguished observers made clear the main features of the act of fertilization. In particular, the great general character of the act was revealed as the coming together into close association of two nuclei—a sperm nucleus from the male parent and an egg nucleus from the female. That the cytoplasm of the two elements was of relatively subsidiary importance was rendered clear both by cases where the egg cytoplasm might exceed by many thousand times the bulk of the sperm cytoplasm without appreciably affecting the operations of heredity, and again by the very varying extent to which the cytoplasm which is present in the male gamete takes part in the actual process of gamatic fusion.

It has also gradually become probable that the special part of the nuclei which is concerned in heredity is that deeply staining portion known as the chromatin. As the Zygote, the original single cell which develops into the individual, goes on with its repeated divisions to form the mass of cells forming the body of the adult, we see how at each cell division the chromatin filaments or rods—chromosomes—become split up with extraordinary accuracy—one half passing to each daughter cell, apparently so as to distribute the hereditary tendencies to the various tissues. The progress of experimental embryology has rendered it probable that the hereditary tendencies carried by the chromatin are definitely localised within its substance—an idea made use of by Weismann in his fruitful speculations upon Heredity and Variation, and which is of special interest now, as in it appears to lie the explanation of the phenomena of "Mendelian" inheritance.

As regards the *cause* of those divergences from perfect in heritance which we call genetic variations—that is to say, variations which are innate in the individual, not impressed upon it by external circumstances—no definite conclusion has been reached. Early in the last quarter of the century Weismann suggested that such variation was due to a peculiar ("reducing") type of division of the chromatin which occurred during the period of maturation of the germ cells, and which resulted in the chromatin of sister germ cells not being precisely equivalent.

Later studies on the phenomena of maturation of the germ cells and fertilization render it highly probable that the explanation of genetic variation does lie along some such lines.

It was as we have seen Weismann, who was able to emphasise the great importance of the distinction between innate or genetic variations, and acquired or somatic variations. The minute study of the early stages of development of certain animals has served to bring out the basis on which this distinction rests. In particular, Boveri, in his beautiful studies of the development of one of the round worms *Ascaris megalocephala*, showed in the most convincing way how the gonad or germ cells was set aside from the body or soma at an extremely early period of development, enabling us to understand how the soma may undergo the most varied kinds of ill-treatment without affecting the progeny arising from the already developed gonad.

CONCLUSION.

If we now glance at the general condition of Zoological Science at the beginning of the new century, we see that the building materials which had been collected during the earlier decades of the past century in a halting and unsystematic manner, and during the last four decades with greater energy and discrimination, have been built together to form a splendid edifice in the science of Morphology—which, if there still remain an infinity of details to be adjusted—is yet fairly complete as regards its broad outlines.

ZOOLOGY OF THE PROTOZOA.

In none of the great Phyla of the animal kingdom has progress been so marked as in the Protozoa. Our knowledge of these forms, practically unknown at the beginning of last century, has in correlation with the evolution of the microscope as an instrument of research, advanced by leaps and bounds, until now at the beginning of this century, we find the establishment of a special Chair of Protozoology, in at least one of our Universities. In the growth of this daughter science, we have been made acquainted with a vast number of different forms which have been classed into subgroups similarly named to those in the other phyla. The tendency of the research of to-day, however, is to show that we must exercise the greatest caution in classifying Protozoa by the characters of

isolated individuals. They appear to show a quite remarkable plasticity in relation to environment, and under an apparently trivial change in environmental conditions the apparently most characteristic features may become completely changed. In these circumstances it would appear that our classifications of Protozoa are in a decidedly unstable condition, and will remain so until our knowledge of life histories becomes much more complete than it is at present. Perhaps the most important advances made during the later years of the century, in regard to Protozoa, have been those which deal not with classification, but with the phenomena associated with the processes of reproduction.

Reproduction is found in its simplest form in the Protozoa, the individual simply dividing up into two or more daughter individuals, the division of the general protoplasm being accompanied by the division of that peculiarly modified part of the protoplasm—the nucleus, which, as we know from experiment, exercises regulative control over the vital processes of the general protoplasm. Prolonged observations by Maupas have rendered it highly probable that this multiplication cannot go on indefinitely without the periodical intervention of a sexual process. By this is meant the temporary or permanent fusion of the protoplasm of two individuals together with the fusion of their nuclei. If a single individual be isolated and kept under favourable conditions it reproduces time after time for it may be hundreds of generations. Eventually, however, there comes a period when reproduction slackens off and the individuals produced are less healthy and finally senile decay and death of the whole brood takes place. If, however, at a particular period individuals of the brood are allowed to conjugate—to undergo sexual fusion—with individuals from another brood, it is found that the resulting individuals have become, so to say, rejuvenated, they can now go on again dividing for many generations, after which, conjugation as before becomes necessary to avert senile decay and death.

The study of these phenomena in the Protozoa has served to shed a bright light upon certain fundamental features in regard to the other forms of animal life. The living substance of the Protozoon is potentially immortal—death being staved off by the conjugation process. Now any one of the Metazoa—including all animals above Protozoa—begins life as a single cell, the Zygote or fertilised egg. As it develops into the adult individual it undergoes cell division over and over again. It behaves just like

the individual from which was started the brood of Protozoa, the main difference being that in this case the daughter generations of cells remain connected together to form the body of the individual, instead of swimming away as separate individuals. Here again, as in the Protozoon cell, multiplication does not go on indefinitely. It slackens off after a certain number of generations, for the brood—the body of the adult individual—attains to a fairly definite size. Finally senile decay and death takes place. Now it would seem that this senile decay and death is due to the same cause as in the Protozoon brood—absence of conjugation. For in the Metazoon we find that somewhere or other in the body there remain one or more masses of cells which—avoiding the specialisation for the performance of various body functions that overtakes the other cells—retain their ancient capacity of conjugating with corresponding cells from another brood—that is to say another body, and when this conjugation is allowed to take place the resulting Zygote is rejuvenated just as in the Protozoon. It escapes death and it multiplies for the usual number of generations so as to give rise to a new brood—a new individual. In these masses of conjugative cells which form the "gonad" of one of the higher animals we see living matter, which is potentially immortal. Death it would seem comes to this living substance of the gonad not of necessity, but only if conjugation be prevented: most frequently it suffers a violent death in the general crash involved in the death of the soma or body in which it is contained.

It is possible that considerations such as these may turn out to have an important practical bearing in relation to many of these biologically very interesting abnormalities known as tumours. In these, particularly in malignant tumours, we see pieces of tissue more or fewer of whose cells have in some way or other their power of multiplication restored to them. By considerations, such as those set forth in the preceding paragraphs, the possibility of the rejuvenescence being due to conjugation having taken place is at once suggested. In the opening years of the new century, investigations on the minute histology of malignant tumours have brought to light certain remarkable types of nuclear division, known otherwise as characteristic of maturing germ cells. Is it not likely that, along with these characteristics of germ cells, these tumour cells will be found to show the other great characteristic of germ cells—the tendency to conjugate?

EMBRYOLOGY.

In Embryology—that department of Morphology which concerns itself with the structure of the individual animal during the stages of its development—the work of the century has sufficed to block out the subject in its main lines. What is now necessary is to develop especially the comparative side of the subject. The working out of the development of special forms in very minute detail has possibly been carried to excess, for there has been too often a tendency to ignore the very important principle of the limit of probable error, which in embryological investigation tends to be very high. An important line of investigation which has, so far, been scarcely touched lies in the comparison between the developmental features of closely allied forms, the eggs of which differ in such characters as quantity of yolk. Some of the genera of Siluroid fishes would be particularly good subjects for such investigations—the size of the egg and its richness in yolk varying enormously between different species. It is only by investigations along such lines that we can hope to achieve the great aim of embryological science, the ability to sift out correctly those features of development which have been recently acquired from such as are ancient and of phylogenetic significance.

THE INDIVIDUAL IN DEVELOPMENT.

Through the greater part of the Nineteenth Century there has been an obvious tendency to look on the animal individual as primarily an aggregation of parts. On the one hand, following the enunciation of the Cell Theory, the animal body has been regarded as primarily an aggregation or colony of cells; on the other hand it has been regarded as being built up of a number of separate organs, each with its own definite little function to fulfil, much as a steam engine is made up of such parts as cylinder, piston and the others. Towards the close of the century we see signs of a realisation that such ways of looking at the animal organism can be carried too far. In regarding the individual as an aggregation of organs we are apt to completely overlook the fact that an organ is merely a specialised part of a whole, in which originally every part was capable of performing all the essential functions. What we find in an organ is not a single function but a number, one or a few of which are conspicuous and are commonly known as *the* functions of the organ, while others

which may once have been conspicuous are reduced, it may be, to such an extent as to be under normal circumstances quite imperceptible. These subsidiary functions of the organ are of enormous importance, because they are at all times liable to increase and assume a conspicuous character. When this happens in the individual we get an abnormal or pathological character arising, when on the other hand it comes about by degrees in the slow process of evolutionary change it affords an example of the familiar but unfortunately named phenomenon of "Change of Function."

It must ever be borne in mind that even in the most complicated organism the organ is primarily a part of the living whole, and that its metabolism is intimately bound up with that of the rest of the body. It would probably be no exaggeration to say that no change can take place in any organ of the living body without influencing to some extent the body as a whole.

So also with the cellular structure of the body. We are tending more and more to see in the individual a mass of living substance which on account of its great increase in size undergoes a *secondary* segmentation into cells. And as regards the structure of the cell itself: in the nuclear substance we see something not fundamentally distinct from the cytoplasm, but merely specialised parts of the protoplasm in which the regulative activity of the cell life has been localised, parts which may remain scattered through the cytoplasm as in many of the lower Protozoa, or may—as is usually the case—be aggregated together into a special conspicuous mass, the nucleus.

IDEA OF CLASSIFICATORY UNITS.

A realisation of the Evolution idea teaches us that these conceptions do not represent actualities in Nature except when we limit our consideration to one period of time. The tree of animal nature may be said to occupy space of three dimensions. The one of those corresponding to height is the element of Time. When we regard organic nature as it exists to-day alone we ignore this dimension, we look not at the tree as a whole, but only at the part of it cut through by a surface representing the present. On this surface we see the sections through the branches and twigs of various orders of importance representing families, genera, species and so on, as if isolated from one another. If we on the other hand could by a complete knowledge of Evolutionary

history bring in this third dimension, we should see that the apparently isolated genera and species of the present moment are really without definite limit.

The idea of species or other classificatory group is seen then to have this limitation. The idea is subject to another important qualification. It has in fact a fairly precise meaning only within the bounds of a single small group of allied organisms.

A collector of butterflies has a fairly clear conception of what "species" means, so also has a collector of beetles, or a collector of molluscs, or a collector of birds, or of earthworms. But this idea is confined only to the group in question. If a student of beetles compares his idea of species with those of a student of moths he will find they differ somewhat though probably to a slight extent. If he talks with a Conchologist or an Ornithologist he will find they differ a great deal, while if he talks with a student of Corals or of Protozoa he will probably fail to discover that their ideas have anything in common. There will in fact be a total absence of common factors through which a comparison can be made.

It is necessary to emphasise these limitations of the ideas of species, genera and other units of classification, for the whole system of such units—so essential to us in practical work—tends to make us magnify their importance. As a matter of fact, were our knowledge of the Evolutionary tree complete, all our classificatory groups would be found to shade into one another by insensible gradations, and the only way of indicating the position of an individual specimen in the tree of life would be by using three numbers to indicate the ordinates of its position.

Centenary Lectures, No. IX.

The Development of Sanitary Science in Britain during the Nineteenth Century. By A. K. Chalmers, M.D., D.P.H. (Camb.), Medical Officer of Health for the City of Glasgow.

[Prepared by request of the Council and delivered before the Society, 5th April, 1905.]

Already one of the lectures by which the Council of the Society has resolved to mark the passing of its first Centenary has been devoted to a review of some of the advances in Medical Science during last Century. On that occasion the distinguished Professor of Pathology in our University—Dr Muir—presented to the Society a review of the growth of knowledge of infective processes in disease, in a manner which, for lucidity and completeness could not well have been surpassed. Yet in a City which itself is witness to so much that Medical Science may do when applied to the prevention of disease, it is not unfitting that the Council of the Society should desire that the review should be extended to include some description of the origin and growth of a system of administration which aims at applying the knowledge thus gained regarding the causes of disease to their prevention. But while sanitary legislation took shape almost wholly during the second half of the 19th Century, the conditions with which it was designed to cope had already attracted much attention, and for more than half-a-century preceding, many of the major problems of Sanitation had been present to many minds, and in some instances had been made the subject of detailed enquiry and report. Some even of the older writers on Medicine,[1] might be quoted to show that a knowledge of the causes of disease was of value for prevention as well as treatment, but what the 19th Century did for Preventive Medicine was to create the mental atmosphere in which disease

[1] Hippocrates, might be quoted in support of the contention that a knowledge of causes has more than a speculative interest, and might be applied to prevention as well as treatment.

came to be regarded not only as a misfortune to the individual, but as a factor in national welfare, and so entitled to some consideration from the State. Moreover its causation was seen frequently to be dependent on environment, and environment was the sum of conditions which might be altered at will.

Stated in simplest terms, our Sanitary code of to-day aims at modifying this environment; and yet, when thus stated, our definition would exclude from review much that is not only essential to our purpose, but formed, in fact, the very groundwork upon which modern sanitation rests. For the doctrine of environment was elaborated not as the result of any speculative groping after facts wherewith to illustrate a theory, but welded from knowledge drawn direct from the crucible of Nature, like iron taken at white heat from the furnace. And here I am led to observe that sanitation to-day stands in some danger from the somewhat conventional horizon with which legislation has surrounded it. To some extent the rapid development of administrative methods may be advanced in explanation of this, but there is some evidence, I think, that we are losing sight of the unity of the problem which presented itself to the early reformers. For the old watchwords may readily become shibboleths, and the term environment lose its significance when used in too restricted a sense.

It is a law of organic life, that development proceeds by differentiation, but it would be difficult, I believe, to find any single illustration in nature where this differentiation or specialisation of function is not directly co-ordinated to the common needs of the body corporate. To apply this analogy to the subject before us, while we find much that is fairly comparable in the differentiation of function in the several parts of the body politic, there are many reasons for thinking that it has proceeded to an extent which threatens to dissipate energy, and that one of the most clamant needs of present day administration is the devising of some method of supervision, which will bring the many functions of Local Administration into co-ordinated action.

For illustration, we need only recall the circumstances of the City in which we are met, in relation to its Educational, its Poor Law, and its Sanitary Administration. Each within its own sphere discharges functions which are essential to the welfare of the whole, yet all are unrelated in their administration. Within

the Municipal area, we have, for Sanitary purposes, twenty-five Sub-districts, corresponding to the Municipal Wards, the whole of Glasgow School Board area, and portions of five others (Govan, Springburn, Maryhill, Cathcart and Eastwood), and no fewer than five Poor Law Parishes (Glasgow, Govan, Eastwood, Cathcart, and Rutherglen), none of which is wholly included. Moreover, neither Police Divisions nor Registration Districts are comparable one with the other, nor with any of those mentioned. It is unnecessary to suggest that for all purposes the several districts should be co-terminous, but it would have obvious advantages (where much sub-division is necessary for special purposes, as, for example, Sanitation), to represent the facts of each for any given larger unit of administration, say, Education or Poor Law. Many uses will occur to you, but the question of taxation alone, is one which we may all appreciate.

While the rating authorities may be multiple, the ratepayer is one, and co-operation on this question alone might afford, to the various spending Departments, an opportunity of arranging expenditure over several years in such manner that the burden could be equally distributed.

Many others more cognate to our subject might be added, such as enquiries into—

(1) The relation of pauperism to insanitary areas.
(2) Of neglected school children to both.
(3) Of Crime to both poverty and insanitation.
(4) Of Insanity to the prevalence of particular diseases. And
(5) Of Home Industries to other conditions of the household.

We need not here pursue this subject further, but I have been led to offer these observations because of the circumstance that the close of the 19th Century found the functions of Poor Law and Sanitary Administration wholly without relation in their executive branches, and with only the somewhat intangible nexus of the Local Government Board of each portion of the Kingdom to represent their common origin in the problems which attend poverty. Yet at the beginning of the Century, Sanitation as a function of Local Authorities was non-existent, its necessity indeed scarcely foreseen. It is true that restrictive interference with the conditions of child labour was already germinating in the minds of the Lancashire Magistrates, for at that time, as you are aware, the country was engaged with the Industrial problems

which the recently introduced Factory System was creating. Moreover, England was staggering under the misuses which had grown up under an alteration in a system for the repression of vagrancy which, rather than the relief of poverty, was the aim of Tudor Legislation on the subject. In Scotland, twenty years later, the Incumbent of St. John's Parish was attacking the whole system of legalised charity as unjust in itself and injurious to the labourer because it took from him every incentive to provide for the future.

With this contrast in the position of Poor Law Relief at the beginning and end of the Century, it is a somewhat striking fact that there should have emerged, as a definite outgrowth from the several enquiries into the conditions of pauperism and poverty, the germ of Sanitary Administration, and that only when the Century was well-nigh half over. Nor is the reason far to seek, for among the most potent causes of poverty is disease, and the prevention of disease becomes in consequence a hopeful auxiliary in the prevention of poverty. But while modern sanitation may be said to have had its birth in this movement, it would not be in strict accordance with fact to suggest that there were no sanitarians before the days of sanitation. There can, indeed, scarcely have been a time in the history of mankind when the avoidance of untimely death was quite a matter of indifference. Hamer has suggested that the troglodyte flint chipper may have suffered from a disease of the lungs now known as "silicosis," as a result of inhaling particles of flint, and that the Aryan with his first effort at domesticating animals may have first arrived at the knowledge that certain diseases of animals were communicable to man. On these points history is silent, but we have the drainage system of Nineveh and the sewerage and water systems of Rome and other cities of antiquity to indicate how far mankind had advanced beyond the primary conception that untimely death threatened him only by the agencies of famine, or drought, or flood. Moreover, the Crusades had brought Leprosy to Western peoples, and Venice in the 15th Century, had already established a Lazarette against Plague.

But the true foundations of 19th Century Sanitary Science lay not so much in the additions to our knowledge of the causes of disease, although these were considerable, as in calling into operation forces which were social and political rather than medical.

Before considering what these were, we may note some of the contributions which the 18th Century made to our knowledge of disease, and its causes, and which paved the way in many cases for advance in the 19th.

PLAGUE, MEADE.—In 1720 Meade published his "Discourse on the pestilential contagion (Plague)," and how it was to be prevented. The disease had at that time reappeared in Marseilles and awakened apprehension lest the experience of its former prevalences in this country should be repeated. The doctrine of contagion was here frankly advocated.

MILITARY HYGIENE.—Sir John Pringle in a work on Diseases in the Army drawn from a wealth of experience obtained as Physician-General to the forces in Flanders in 1742-3 began hygienic reform in the Army. He associates the putrid air arising from filthy surrounding with the dysentry and autumnal fever occurring among the troops. He deals also with the subject of ventilation of hospitals with reference to the prevalence of Jail fever (Typhus) in them.

SMALLPOX.—Early in the Century, Lady Mary Wortley Montague had been the means of introducing from Constantinople the practice of inoculation for Smallpox, and so great was the dread of the disease in an unvaccinated community that the practice of inoculation became prevalent. Jenner made his great discovery in 1795. It was published in 1798, but only in 1840 was the First Vaccination Act passed.

LEAD POISONING.—It was known that the consumption of Devonshire cider produced symptoms which did not follow the use of the beverage as manufactured in other counties in England, but it was not till 1767 that Sir Geo. Baker surmised that these symptoms were due to lead, and an analysis of the Devonshire product confirmed the suspicion. It gained access from the apparatus used in making and storing the cider.

SCURVY.—The discovery that vegetable juices prevented Scurvy dates from early in the 17th Century (1603), but the issue of lime juice to the crews of Merchant Ships, was only occasional even in the 18th Century, and its issue to the Royal Navy dates only from 1795. Haslar Naval Hospital is a witness to the extent to which this disease once pre-

vailed among our seamen. In 1776, the Copley Medal of the Royal Society was presented to Captain Cook for preserving the Health of the Crew of one of His Majesty's Ships during her late voyage round the world. During a voyage extending over 3 years, of a crew of 118 men only 1 died from disease (consumption).

TYPHUS FEVER.—This fever was extremely prevalent during the 18th Century. In the 16th Century, the Black Assizes at Oxford and similar occurrences elsewhere had served to mark the neglected condition of prisons and prisoners, but it was not till Howard was appointed High Sheriff of Bedfordshire in 1773, that the overcrowded and insanitary condition of prisons received the attention which they deserved, and prison reform practically began in the following year. The result was not only to abolish jail fever, but to improve the sanitary condition of prisons to a degree which led Sir Robert Christison to observe that the "best (most Sanitary) place for a man to live in" was a prison. Pringle as we have seen was working on similar lines.

DISEASES OF OCCUPATION.—These had already attracted some attention, and in 1703, Ramazzini, a professor, of Padua, had issued from Utrecht a work thereon, which in 1746 was translated into English by Dr Robert James. A clear distinction is drawn between the diseases which result from the materials of manufacture (among the workers in copper, iron, pigments, etc., for example,) and those other diseases of over strain, of which Writers' Cramp is an illustration. In a quaint passage, he forestalls the advocate of physical education of the present day, "All the men of learning" he says, "used to complain of a weakness in the stomach." And he quotes Celsus as saying, "A great many of the inhabitants of cities and towns, and almost all the lovers of learning have weak stomachs. There is no hard student almost but complains of his stomach; for while the brain is employed in digesting what the desire of knowledge and the love of learning take in, the stomach cannot but make an imperfect digestion of the aliment, because the animal spirits are diverted and taken up in the intellectual service." The work thus begun was extended by Thackrah, a surgeon of Leeds in 1831.

VENTILATION.—The recognition that foul air was productive of disease, entered as we have seen, into Sir John Pringle's contribution to the aetiology of Jail fever. In 1741, Dr Stephen Hales described to the Royal Society an instrument which he had designed, whereby as he says "Great quantities of fresh air may with ease, be conveyed into mines, jails, hospitals, workhouses, and ships, in exchange for the noxious air," and the science of ventilation thus begun was to be turned to good account when the physiology and chemistry of respiration were better understood; and Arnott among others had demonstrated how potent a factor rebreathed air could become in the production of lung diseases.

In other spheres, also, forces were at work which were shortly to play no inconsiderable part both in our national development and in the growth of a system of applied hygiene.

Already, in 1738, the fly shuttle had been introduced into Bury in Lancashire, and the end of the Century was to see industry transferred in great part from the home to the factory.

Moreover, the mission of the Brothers Wesley and of George Whitefield, beginning wholly as an evangelical movement, was soon to reveal the degrading conditions under which much of the industrial work of the country was conducted, and amongst which the workers lived.

More than all, the revolt of the American Colonies and the sublime tragedy of the French Revolution directed men's thoughts to forms of government. England was awakening from the period of inglorious ease which followed the Hanoverian Succession, and the country was entering on a new birth. John Richard Green has happily described these movements as the growth of a larger sympathy of man with man—to Sir John Simon they form the "new momenta" which brought with them the introduction of a new humanity in British politics. The conditions of industrialism revealed the struggles of the poor and their hardships. "Poverty began," says Sir John Simon, "to be considered, as perhaps never before, by the prosperous portions of the community, not merely as subject to privations, but as complicated with the helplessness of ignorance, and aggravated by disease; and the study of the causes which are degrading in social life were seen to be more urgent religious problems than some which had exercised the Schoolmen and Mystics."

It would appear, however, that the first step which the Legisla-

ture took to give effect to their newly acquired convictions was unhappily chosen, becauses abuses of such magnitude crept into the administration of the Poor Law Act of 1796, that when the Commission of 1832 came to report on its operation, they found themselves justified by the facts which they had collected, in recommending an almost entire reversal of the custom of giving indiscriminate relief, and almost unconsciously, as it were, laid the basis of many reforms which were to follow. For, amongst its direct results, we may include the revival of a spirit of independence in the worker, the development of the principle of co-operation, the growth of Friendly Societies and of Trade Unions—the ascent of the worker, indeed, from the perils of pauperism, with which mal-administration and ill-devised legislation had surrounded him.

Here the genius of Chadwick revealed itself, and although others were associated with him in the work, it is to his writings, and later to those of Sir John Simon, that we turn for demonstration that among the most constantly operating causes of poverty was to be included disease which was the result of the conditions amongst which the labourer lived and worked. Chronologically, the enquiry into the operation of the Poor Laws and the causes of poverty preceded, and to some extent was directly operative in producing the Health of Towns Commission, from whose labours emerged the first general Public Health Act of 1848. Certain Local Acts, it is true, preceded this, and the more formidable pandemic diseases, like Plague and Cholera, had in former times given rise to spasmodic efforts to meet the local emergencies which their advent created, but the Act just quoted was the first of its kind to attempt the work of reforming the local conditions which constantly tended to produce high rates of mortality, and afforded the ground-work which the major epidemic diseases required for their uncontrolled development.

FACTORY LEGISLATION.—In a further direction also, the Legislature had broken new ground, and with the birth of the century the basis of a system of industrial legislation was begun, which in time was to play an important part in controlling the conditions of work which were injurious to the health of the worker. We have already seen, during the 18th Century, that a causal relationship had been established between certain forms of industry and particular diseases, but the rise of the industrial

system towards the close of that Century produced new dangers which rapidly attracted attention. In particular the inhuman conditions attending child labour led the Magistrates of Lancashire in 1784 to declare that these children should no longer be permitted to work during the night, and not more than 10 hours per day, but it was only in 1802 that the first Factory Act was passed, bearing the title of the "Health and Morals of Apprentices Act." Factory Legislation thus had its beginning in increased care of child life, and although as Hutchins and Harrison contend, it was rather an extension of the Elizabethan Poor Law relating to Parish Apprentices, it is a further illustration of the unity of the problem with which social legislation deals, because, while restricting the working hours of the apprentices, it provided also that they should be taught reading, writing, and arithmetic. Education, in fact, entered as a side issue to factory legislation.

Nor can we omit the operation of outbreaks of epidemic disease in helping to mould the legislation of the period. We have seen how the labours of Chadwick, and of other Poor Law Commissioners were emphasizing in successive reports how large a proportion of pauperism was due to disease and death from preventable causes. Cholera made its first appearance in this country in 1831-2, to stimulate further interest in questions of public health. Moreover, the great social feature of last century, to wit, in the massing of populations in large centres, was teaching mankind after its own fashion. "For to the hygienist of the middle of the 19th Century, the widespread incidence of the major epidemic diseases, and their tendency every now and again to leap into epidemics of considerable magnitude, made their control a matter of imperious necessity. They saw the industrial centres of Britain scourged with ever recurring epidemics of typhus fever; cholera, even so recently as the 60's decade, spreading westward through Europe, and apparently presaging a renewal of the outbreaks which the earlier years of the century had witnessed, pulmonary phthisis moving uncontrolled among the very flower of the industrial community."[1] Yet amidst the confusion which the rapid succession of occurrences of this character was calculated to produce, the ground-work was being laid, in the accumulating records which the Registration Act of 1837 had

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[1] Some use has been made here of an article by the writer in the *Annals of the American Academy of Political and Social Science.* March, 1905.

introduced, on which, and indeed out of which, the genius of Dr Farr was soon to construct an instrument by which life and disease in relation to environment might be expressed with something approaching scientific exactness. For, without the means of measuring results, the results themselves became of doubtful significance, and to Farr and the monumental system of Vital Statistics which is associated with his name, more than to any other single worker in the whole field of hygiene, we owe the science of public health as we to-day know it.

The circumstances which the Health of Towns Commissioners disclosed will be sufficiently illustrated in a quotation from the evidence of one of the witnesses—Dr Southwood Smith:—"In every District (he is referring especially to East London) in which fever returns frequently and prevails extensively, there is uniformly bad sewerage, and bad supply of water, a bad supply of scavengers, and a consequent accumulation of filth. The streets, courts, alleys, and houses in which it becomes most prevalent and fatal are invariably those in the immediate neighbourhood of uncovered sewers, stagnant ditches and ponds, gutters always full of putrifying sewage, which is openly exposed and seldom or never removed. It is not possible for any language to convey an adequate conception of the poisonous conditions in which large portions of these districts always remain . . . . from the masses of putrifying matter which are allowed to accumulate." Local colouring of a like character is contained in the Report of Dr Neill Arnott regarding the conditions of the Wynds in Glasgow, and Sir Edwin Chadwick, writing of this visit, says—"It might admit of dispute but on the whole it appeared to us that both the structural arrangements and the condition of the population of Glasgow was the worst of any we had seen in any part of Great Britain." But the conditions described were not peculiar to town districts. "The most important evils (says the Report) affecting the public health throughout England and Wales are characterised by little variety, and it is only in the degree of their intensity that the towns exhibit the worst examples of such evils. Villages and clusters of houses inhabited by the poor, are often under the influence of the same causes of disease, though their effect in such situations may be frequently rendered comparatively slight from the more free circulation of the external air. The vitiation of the atmosphere from overcrowding and absence of proper ventilation in individual apartments, produces in the rural districts

the same diseases that arise from the same causes in a town population." Here be it observed there is not one word of a theory advanced by which to explain the connection between disease and environment, but a plain and simple recognition of their association. And probably for this reason, the recommendation of the Commissioners, and the first Public Health Act deal mainly with such questions as sewerage, paving, scavenging, the abatement of nuisances, the regulation of Offensive Trades, width of streets, courts, and alleys, cellar dwellings, the ventilation of public buildings, and the regulation of Common Lodging-houses.[1] The power to provide Hospitals emerged later, in an Act which extended the provisions of the Disease Prevention Acts originally designed to deal with Cholera and like diseases.

Now, if we endeavour to estimate results, I shall, in preference to contrasting the death-rates from individual diseases, quote an appreciation of their value by Sir Robert Giffen.—

"Dealing with Mr. Noel Humphrey's paper on 'The Recent Decline in the English Death-rate' (which was based on a comparison of the death-rates 1838-54 and 1876-80, and the increased expectation of life in the later period) Sir Robert observed with regard to Mr Humphrey's conclusion that 'the larger proportion' of this 'is lived at useful ages and not at the dependent ages of either childhood or old age' that 'the figures to be affected relate to such large masses of population that so great a change could not have occurred if only a small percentage of the population had been improved in health.'"

In the periods thus compared, the average duration (or expectation) of life among males rose from 39·9 to 41·9 years, and among females from 41·9 to 45·3 years, while Dr. Tatham has shown that in the decade 1881-90, it further increased to 43·7 for males, and 47·2 for females.

"It is natural to regard these results as in some measure reflecting the work of local sanitary and other authorities during a whole generation of fairly continuous effort. Factory legislation had improved the conditions, and in many instances had shortened the hours of labour. Local Authorities had introduced water supplies and improved systems of drainage. Much attention had been given throughout the country to the conditions

[1] See the Report and Act and a very comprehensive account of its genesis by Dr Franklin Parsons in the *Transactions* of the Epidemiological Society, N.S. Vol. xviii.

of housing, large areas of badly constructed tenements and badly arranged streets had been cleared in the large towns, and building regulations had been devised to control the erection of houses, so that the primary requirements of light and ventilation should be met, and the evils arising from unsuitability and impurity of site prevented. Continuous effort had been made to prevent the overbuilding of sites and the overcrowding of rooms; greater purity of soil water and air was constantly aimed at, and above and beyond all this, the economic condition of the worker had been improved, the purchasing power of money had increased, and the cost of food stuffs been reduced."

But the increasing attention which was being directed to the physical requirements of healthy living was soon to bear fruit in other directions, and Cholera became the means by which the new doctrine of water-borne diseases was placed on a scientific foundation. In 1849, during the second invasion of the disease, Dr Snow published a short paper to show that the intestinal discharges of the sick were capable of propagating the disease, and in 1854 he was able to demonstrate, in the now classical instance of the Broad Street pump, that when these gained access to a water supply, a wide-spread distribution of the disease occurred. From this point of view, Cholera may be regarded as a true sanitary reformer, for, once the doctrine of a specific contagion was fairly grasped, its application to the endemic fevers of the country was certain, although years were to elapse before the organism of some of these diseases was to be discovered. Among the more prevalent and fatal infectious diseases of this period, the name "Typhus Fever" was applied indiscriminately to all which presented certain clinical features, of which delirium and stupor were the type; but, already, Stewart and Jenner were at work discriminating between that form which still goes by the name, and others, which are now recognised as Typhoid, or Enteric, Fever. And it affords striking testimony to the importtance of the work which epidemiology, proceeding along the lines of strict inductive reasoning, has done for mankind, that Typhus Fever has been reduced from a scourge which was constantly recurring to its present stage of sporadic occurrence only, without any organism specific to the disease having yet been discovered.

To the 19th Century then we owe the doctrine of the water carriage of disease, and, since Snow's time, the part which

polluted water supplies play in disseminating disease has frequently been demonstrated. And it only required an extension of the doctrine to other articles of consumption, to pave the way for the inclusion of milk, and indeed, of other articles of food similarly contaminated. More than this, it displaced the conception of an infecting process, as being necessarily operative only at its point of origin, and prepared the ground for much of the epidemiological work of after years. Much of the work of the present Royal Commission on Sewage has been directed to a consideration of the question of oyster and other shell-fish infection in sewage polluted estuaries; and, just as the century closed, an entirely new field of enquiry has been opened up by the suggestion—and in one or two instances, the demonstration—that insects may become the carriers of infectious disease.

In the main, however, epidemic diseases were but the taller growths of the forest, which compelled attention to the soil on which they grew, and to the character of the undergrowth. Cholera could gain epidemic intensity only where diarrhœa was always present. Typhus fever, Hospital fever, Jail fever, Ship fever—because by all of these it has at one time or another been known—prevailed in circumstances productive at all times of a high mortality from lung diseases. To lessen the prevalence of diarrhœa, was equivalent to reducing the probabilities of a cholera epidemic, and the prevention of epidemic disease was part only—although a more obvious part—of the new functions which Government had undertaken in legislating for the control of conditions on which disease generally could be shewn to depend. And so the physical conditions of healthy living, extending from the place of living to that of occupation, came to imply a knowledge of food supply, housing accommodation, nature of occupation, and its effect on the health of the worker, the provision of hospital accommodation for the sick poor, and, latterly, of the infectious sick; and, as legislative result, we have the Sale of Food and Drugs Act, several Factory and Workshops Acts, consolidated and extended in the present Act of 1901, the Dairy Clauses of the Contagious Diseases Animals Act, the Alkali Works Regulation Act, several Artisans Dwellings Acts, now represented by the Housing of the Working Classes Act of 1890, in addition to the general Public Health Acts, and several local Acts of a supplementary character.

Reference to a few of the more important advances which the

epidemic history of the century has witnessed, may serve as further illustration of the work of Preventive Medicine.

SMALLPOX AND VACCINATION.—We have seen that the value of Jenner's discovery of the protective power of vaccination was recognised in the Act of 1840, which offered vaccination to any who desired it. This was followed by the Act of 1853 which made infantile vaccination compulsory, and the next important step was the recognition of the Conscientious Objector in England in the Act of 1899. Smallpox returned with great malignancy in the early '70's, but with an altered age incidence of fatal attacks, which had lessons of its own. Infancy ceased to be the period of life wherein the greatest fatality occurred, and adults suffered largely by reason of imperfect vaccination in youth. It demonstrated that the protective power of vaccination had a time limit, and that protection from fatal attack continued beyond the period of protection from attack itself. Again, after another interval, roughly of thirty years, Smallpox has returned to suggest that it has a cyclical movement in populations depending wholly on infantile vaccination. The last quarter of the century also served to direct attention to the danger to neighbouring populations, which attended aggregation of the sick in hospitals.

TYPHUS FEVER.—We have seen that throughout every enquiry into the sanitary conditions under which the people lived, the prevalence of fever was associated with the depressing conditions which poverty, overcrowding, and uncleanness, engendered. Fever, however, in the early days of sanitation, was rather a generic title than the name of a particular disease; but, with the separation of Typhus from Enteric fever, the former was seen more closely related to overcrowding and destitution.

Hence arose much strenuous action on the part of Local Authorities to reform the conditions of housing because, although the question itself had emerged at an earlier period, the term "fever den" had come to signify much that in later years was described as a "slum." In every city, which has had to cope with Typhus fever prevalences, houses which were "back to back," "one room deep," "open only to the front," became not only terms of reprobation, but were descriptive

of conditions which violated every principle of healthy living, and were intimately associated with disease.

PHTHISIS may be said to have been brought definitely within the region of practical sanitation by the Report prepared for the General Board of Health in 1858 by Dr. Greenhow. Considerations also of its relative incidence in males and females brought into prominence its relation to the several forms of industry, in so far as these produced conditions of respiratory impurity, whether arising solely from simple lack of air supply, or were accompanied in several industries by dust added to the air of respiration from the materials used in manufacturing processes. Subsequent enquiries were to shew the favourable influences resulting from the drying of soils through the introduction of systems of drainage; and the close of the century witnessed the origin of a popular movement for the suppression of the disease, which directly owed its origin to the discovery of the micro-organism, with which the disease is associated.

In a century which brought sanitary perils of its own, the history of its sanitary development is not one of the least stimulating. "Urbanisation" to an extent quite unparalleled in the past created a civic responsibility and an organised life of its own. It enforced in the open the experience which had stirred the sympathies and efforts of Howard and others towards gaol reform. By the stern logic of fact town populations were taught the lesson that uncontrolled aggregation of populations was a menace; but, with an urban population which, in the last half of the century, increased from 55 to 77 per cent. of the whole, while their death-rates fell to the level—sometimes, indeed, below the level of the country formerly,[1] we may claim that some part of the lesson has been learned.

Sanitation proposes for the individual conditions of life and work which will satisfy the physiological demands of his being. And because our populations are now freed from much of the

[1] The effect of an altered age-constitution should here be remembered. When correction is made for this by applying the death-rates for Scotland in 1901 to the population of 1871, *on the basis of a similar age distribution*, the death-rate of that year is reduced from 22·2 to 21 per 1,000. So that *without any alteration in sanitary circumstances*, an alteration in age-constitution alone would have produced a reduction in the death-rate of 1 per 1,000. This is one of the results of a decreasing birth-rate.

grossly impure conditions which formerly surrounded them, it is probable that we can see the problems of sanitation in a truer relationship to the economic basis of individual life, and may recognise as frankly contributing to the result after which sanitation strives, the operation of every agency which has the promotion of individual well-being as its object. Preventive Medicine may pave the way along which Education may carry man to ever higher conceptions of destiny, but it cannot of itself make progress when uncontrol in the individual is dominant and hope is dead. The 19th Century leaves us with the finger of warning pointing to hitherto unreclaimed portions of all our communities. According to the point of view of the particular writer these are the educationally defective, the industrially inefficient, the population of the slums, the whilom inhabitant of the poorhouse and jail, the parasite of civilisation. It is with these we must get into closer contact.

But terms so wide in their significance, only serve to indicate the diversity of the problem. Many workers are at work, but few proposals hitherto have met with conspicuous success. I believe we, in this city, might advance the solution more than we do by selecting an area, and directing every educational, poor law, and sanitary agency we possess towards a combined study of the causes at work. We should then have a clinical demonstration of disease of the social organism, and might perchance discover something further of its causes. Should we find that some of them, like some bodily diseases, are incurable by means presently available we should still benefit by the knowledge, and find stimulus for further work.

Some early Grammars and other School Books in use in Scotland more particularly those printed at or relating to Glasgow. By DAVID MURRAY, M.A., LL.D.

PART FIRST.

[Read before the Historical and Philological Section, 16th December, 1904.]

FOR many centuries the *Ars Grammatica* of Aelius Donatus was the standard school book in Scotland, as it was in other countries. Wyntoun writing in the fifteenth century says:

> Donate than wes in his state,
> And in that tyme his libel wrate,
> That now baryns oyssis to lere
> At thar begynnynge of gramere.[1]

In 1507 James IV. granted to Walter Chapman and Andrew Myllar the exclusive privilege of printing certain books, so as to prevent their importation from abroad.[2] In 1509 they complained of a violation of this privilege and the Privy Council granted an interdict against the persons complained of, and forbad the printing or importing of "Donatis and Ulric *in personas* or uther books that the said Walter hes prentit ellis."[3] The inference therefore is that Chapman had, prior to this time, printed in Scotland an edition of Donatus. "The grace buke, prymar and plane donat" were in use in the Edinburgh Grammar School in 1519;[4] and in 1567 Robert Lekpreuik had exclusive licence to print "the buikis callit Donatus pro pueris, Rudimentis of Pelisso . . . the Psalms of David with the inglis and latine catechismes les and mair."[5]

[1] *Wyntoun, The Cronykil of Scotland*, V., 3443 (Amours); 3377 (Laing).

[2] *Fourth Annual Report of the Deputy Clerk Register*, p. 16, Edinburgh, 1810, fol.; *Miscellany of the Maitland Club*, ii. p. 5; Lee, *Memorial for the Bible Societies*. Appendix, p. 1.

[3] Lee, *supra* Appendix, p. 3; *Additional Memorial*, p. 32.
I cannot identify Ulric *in personas*; it may have been part of the *Codex Udalrici* of Ulrich of Bamberg, author of *Ars dictandi*.

[4] Town Council Minute, 10th January, $15\frac{19}{20}$; *Burgh Records of Edinburgh*, p. 193 (Burgh Records Society).

[5] Lee, *Memorial, supra* Appendix, p. 6.

A later grammar, but one which long held the field, was that of Jean Despautère (Flemish, Van Pauteren) of Ninove in Flanders—the Priscian of Belgium—who died in 1520.[1] His *Orthographiae Isagoge* was first published at Paris in 1510;[2] the *Rudimenta* in 1512; and the *Syntaxis* in 1515. The whole were collected in one volume, under the title *Commentarii Grammatici*, and published at Lyons in 1536 in 4to, and at Paris in 1537 in folio. An abridgment by Sebastian Novimola, a Canon of Cologne, appeared at Antwerp in 1566, under the title *Grammaticae Institutionis Libri vii*, which was reprinted at Edinburgh by John Ross in 1579, by Andrew Hart in 1621, by Thomas Brown in 1677,[3] by John Reid in 1684,[4] and by James Watson in 1709. Despauter's *Syntaxis* was also published by Ross in 1579. Jean Pelisson, Principal of the College of Tournon, prepared another abridgment which was first published in Lyons in 1530, and was used to a considerable extent in our schools, but apparently was not reprinted in Scotland,[5] unless it be the "*Meditationes in grammaticam Despauterianam*" for which Master William Nudrye had a licence in 1559.[6]

The list of school books included in Nudrye's patent is interesting and instructive. They are:—

1. Ane schort Introductioun elementar degestit into sevin breve taiblis for the commodius expeditioun of thame that ar desirous to reid and write the Scottis toung.
2. Orthoepia trilinguis.
3. Compendiariae Latinae linguae Notae.
4. Calographiae Index.
5. Tables manuell brevelie introducing the unioun of the partis of Orisoun in Greik and Latene speiches with thair accidentis.
6. Meditationes in grammaticam Despauterianam.
7. Meditationes in Publium memographum et Sapientum Dicta.
8. Trilinguis literaturae Syntaxis.

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[1] He had only one eye as we learn from his epitaph;—
Hic jacet unoculus, visu praestantior *Argo*,
Nomen Joannes cui Ninivita fuit.

[2] *Bibliotheca Heberiana*, Part III., No. 1160.

[3] Lee, *Catalogue*, Part I., No. 3011.

[4] There are copies of the editions of 1677 and 1684 in the British Museum.

[5] A copy of Pelisson's *Rudimenta primae Latinae grammaticae*, Paris, 1560, 12mo., appeared in William Blackwood's *Catalogue*, No. 15,154, Edin., 1812, 8vo.

Pelisson also wrote, *Modus examinandae constructionis in oratione*. Paris (Stephanus) 1529, 12mo; 1535, 4to. It is appended to the *Rudimenta* of 1560.

[6] *Registrum Secreti Sigilli*, xxx. fol. 5a.

9. Trilinguis grammaticae questiones.
10. Ane instructioun for bairnis to be lernit in Scottis and Latin.
11. Ane regement for educatioun of young gentillmen in literature and virtuous exercitioun.
12. Ane A B C for Scottismen to rede the Frenche toung with ane exhortatioun to the nobles of Scotland to favour their ald freindis.
13. The geneologie of Inglishe Britonis.
14. Quotidiani sermonis formulae, e Pub. Terentii Aphri comediis decerptae.

This list is a remarkable one and shows that, on the eve of the Reformation, school children were taught not only Latin and Greek, but also Scotch and French, from specially prepared School books. The phrase "young gentlemen" is also worthy of note. We are apt to look upon it as a piece of snobbery of recent times, but it is of quite respectable antiquity.[1]

The first book produced for a Scotch printer was in 1505 and was a school book.[2]

The earliest Latin grammar written by a Scotsman seems to be the *Rudimenta puerorum in artem grammaticalem* of John Vaus, humanist or professor of Latin in the College of St Mary (afterwards King's College) Aberdeen. It was published at Paris[3] in 1522, a second edition in 1531, and a third edited by Theophilus Stuart, his successor in the Humanity Chair at Aberdeen, in 1553. All are of the greatest rarity. There is a copy of the edition of 1522 in the library of King's College, Aberdeen. Thomas Ruddiman had a copy[4] and there was one in David

[1] See Complaint, 16th December, 1580, by the Privy Council of the inconvenience to the realm "by the education of great number of *yonge gentlemen* and other her [Queen Elizabeth's] subjects in the partes beyond the seas." Peck, *Desiderata Curiosa*, I., p. 99, London, 1779, 4to. A century later we have Walker's *Education of young Gentlemen*, Oxford, 1677, 8vo. In 1747 James Scruton, Writing Master and Accountant, was invited by the Provost and other gentlemen to come from London to Glasgow "to qualify *young gentlemen* in writing, arithmetic," etc. *Glasgow Courant*, 16th June, 1749. Todd's *Schoolboy and Young Gentleman's Assistant*, was published at Edinburgh in 1748. Well's *Young Gentleman's Astronomy, Chronology and dialling*, London, 1718, 8vo.

[2] *Multorum Vocabulorum Equiuocorum Interpretatio* by Joannes de Garlandia, Rouen (for Androw Myllar), 4to. Dickson and Edmond, *Annals of Scottish Printing*, pp. 29, 32. Probably a reprint of Wynken de Worde's edition of 1499.

[3] Of books by Scotsmen sent abroad to be printed for want of facilities at home. See Lee, *Memorial for the Bible Societies*, p. 10.

[4] *Bibliotheca Romana*, p. 10.

Laing's library.[1] There was an Edinburgh edition by Robert Lekpreuik, 1566, 4to, which is also exceedingly rare.[2]

The next grammatical work by a Scotsman was a Latin translation of Linacre's *Rudiments* by George Buchanan, Paris, 1533, 8vo, with a dedication to his pupil Gilbert Kennedy, Earl of Cassillis. It passed through upwards of ten editions in France in thirty years, but does not seem to have been reprinted in Scotland, although his tract *De emendata structura Latini sermonis*, was used in the High School of Edinburgh in 1579. Buchanan added to the translation of the *Rudiments* the tract of Ludovicus Vives *De ratione studii puerilis*. Linacre's *Rudiments* is a concise compendium of Latin grammar, intended for beginners and to be supplemented by oral explanations by the teacher. After the accidence come the Rules of Construction with a Supplement upon the same subject. The latter may have been composed by William Lily or some one associated with him, as his name frequently appears—*e.g.*, *Lilius praeceptor*, *Lilius magister.*

After the Reformation we have George Buchanan's *De Prosodia Libellus* published by Waldegrave in 1595 or 1596,[3] then by Andrew Hart in 1621, and often afterwards. It was prepared as part of an intended grammar to be used in the Grammar Schools of the country, to the exclusion of all others,[4] but the scheme, like many of a similar kind, came to nothing. Instead of uniformity, each teacher used the grammar that he thought most convenient, and many books of the kind were issued in Scotland. A long list of these will be found in the Catalogue of the library, prepared by himself, of the great grammarian Thomas Ruddiman.[5]

Taking this list as a foundation, the books in use included :—

1. and 2. Vaus and Buchanan, just mentioned.

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[1] *Catalogue*, Part I., No. 3699. This copy lacked a few leaves.

[2] There was a copy in George Chalmers' library (*Catalogue*, Part III., No. 1127), which he purchased at Constable's Sale in 1801.

[3] There is a copy in the library of the University of Edinburgh. This is probably the copy which appeared in William Blackwood's *Catalogue*, No. 11,409, Edinburgh, 1809, 8vo.

[4] Act of the Privy Council, 15 December, 1575. Lee, *Additional Memorial*, p. 156. Appendix No. LIX. Parliament in 1607 appointed another Commission to fix upon one common grammar to be used in all Grammar Schools. *Acts of the Parliament of Scotland*, IV., p. 374.

[5] *Bibliotheca Romana*, pp. 61-63. Edin., 1757, 8vo.

An early list of books in use in Grammar Schools in England will be found in John Brinsley, *Consolation for our Grammar Schooles*, p. 59. London, 1622, 4to.

3. Rudimenta Grammatices in gratiam iuventutis Scoticae conscripta.

Edinb., 1580 and again 1587, 8vo.

popularly known as "the Dunbar Rudiments," by Andrew Simson, master first of the Grammar School of Perth and afterwards of that of Dunbar.[1]

It was issued again in 1599, 1607, 1612 and 1639.

Simson was one of the Commission, appointed in 1575, for the purpose of suggesting a remedy for the multiplicity of Latin Grammars then in use; and he drew up the *Rudimenta* with the object of providing a standard grammar. While it did not effect this purpose it was very popular, and passed through many editions down to at least 1709. One of these, and a very neat one, was issued at Glasgow in 1693, and will be mentioned more at length hereafter.

4. Grammaticae latinae, de Etymologia, Liber secundus.

Cantebrigiae, 1587, 4to.[2]

Dedicated to King James VI.

This was intended as part of the general Grammar, to which reference has been made. It was by Mr James Carmichael "a person of rare piety, genius and profound scholarship." He held the united offices of minister of the parish and rector of the classical school, Haddington.[3] The latter appointment, to which he was chosen in 1572, did not yield him more than forty pounds Scots a year of salary, and a shilling quarterly from "ilk toun's bairn." In 1576 at the request of the Town Council he resigned the position of school master and confined himself to his ministerial duties.[4] He took refuge in England in 1584 to avoid prosecution for a political offence; but returned to Scotland in 1588, and was reinstated in his pastoral charge.

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[1] The authority for the edition of 1580 is Ames' *Typographical Antiquities*, ed. Herbert, p. 1501. David Hume of Godscroft inscribes his Elegies "Ad Andream Symonidem, ludimagistrum Dumbarensem praeceptorem meum."

Simson married Violet, daughter of Archbishop Adamson. M'Crie, *Life of Andrew Melville*, p. 461. Edin., 1856, 8vo. See further as to Simson, *Ib.*, pp. 369, 382, 388; *Select Biographies* (Wodrow Society), pp. 65, 71, 72.

[2] There is a copy in the Advocates' Library, Edinburgh. There was one in the Harleian library. *Catalogus Bibliothecae Harleianae*, Vol. II., No. 15,510. See Ames' *Typographical Antiquities*, III., pp. 1414, 1418. London, 1790, 4to.

[3] For payments in 1576 to Carmichael at Haddington, see *Maitland Club Miscellany*, II., p. 45.

[4] Steven, *History of the High School of Edinburgh*, p. 59.

On the verso of the title-page there is a Morning Prayer on entering school.

The author gives a list of authorities, amongst whom are George Buchanan and Vasius, Scotus, that is, John Vaus.

Some of his renderings are interesting :—

Alnus,	an Aller.
Acer,	a Sauch.
Talpa,	a Modiwart.
Bubo,	an Howlet.
Perdix,	a Petrick.
Culex,	a Mige.
Anser foeta,	a bruid Guis.
Monile,	a Brotch or Bend.
Cancelli,	a Tirlets.
Pugio,	a Quhinger.
Auctio,	open sale of goods.
Harpago,	a Creiper.
Cardo,	a Dure cruik.
Splen,	the Melt.
Pulvinar,	a Boustar.
Papaver,	a Chesbow.

5. Latinae Grammaticae, Pars Prior, sive Etymologia Latina in usum rudiorum.
Edin., 1599, 8vo,[1]

by Andrew Duncan, master of the Grammar School of Dundee.[2] It was intended as an improvement upon Despauter and to make everything plain to the meanest capacity.

Duncan also edited the *Rudimenta Pietatis*, one of the standard Scottish school books, which will be referred to presently,[3] and wrote *Stvdiorvm puerilivm Clavis*.[4]

6. Appendix Etymologiae ad copiam Exemplorvm,
Una cvm Indice interprete.
Edinb., 1495 (mistake for 1595), 8vo.

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[1] Not 1597, as in the *Bibliotheca Romana*. There was a copy of the Grammar along with the *Rudimenta Pietatis* and Buchanan's *De Prosodia Libellus*, Edin. 1595, in William Blackwood's *Catalogue*, No. 11,409, Edin., 1809, 8vo. There is a copy of this Grammar—presumably this copy—in the library of the University of Edinburgh.

[2] As to Duncan, see M'Crie, *Life of Andrew Melville*, p. 382. Edin., 1856, 8vo.

[3] Edinb., 1595, 8vo. There is a copy in the Advocates' Library, Edinburgh. See *Catalogues of Scottish Writers*, p. 85, Edinburgh 1833, 8vo. Allibone, *Dictionary of English Literature*, s. v. Duncan.

There is a copy in the library of the University of Edinburgh.

This is also by Andrew Duncan, and is an Appendix to No. 5. They were reprinted by the English Dialect Society.[1]

7. Stanbrigii Vocabula . . .
Edinb., 1596, 8vo.[2]

This is the celebrated Vocabulary of John Stanbridge (1463-1510), Master of the Hospital of St. John at Banbury, revised and edited by Thomas Newton.[3]

It was again printed at Aberdeen, 1631, 8vo, and Edinburgh, 1644, 8vo, and 1666, 8vo.

8. Grammatica nova in usum Juventutis Scoticae.
Edinb., 1612, 8vo.

by Alexander Hume. Hume, as we learn from his Preface, was a pupil of Andrew Simson, and was educated at the Grammar School of Dunbar and the University of St Andrews, where he graduated M.A. in 1574. He epitomised Buchanan's *History* "in a good style."[4] He spent sixteen years as a student and teacher in Oxford, and in 1596 returned to Scotland where he became master successively of the High School of Edinburgh, of the Grammar School of Prestonpans, and of the Grammar School of Dunbar.[5] Hume's grammar was appointed by Parliament to be taught in schools, but notwithstanding this and although the author thought it superior to the grammars of Despauter, Vives, Ramus and Pelisson, it did not make much headway.[6]

He also wrote,

Prima Elementa Grammaticae in usum Juventutis Scoticae.
Edinb., 1612, 8vo.[7]

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[1] Edited by the Rev. W. W. Skeat and Dr. John Small; *Reprinted Glossaries, Series B*, No. XIII. London, 1874. 8vo.

[2] There is a copy of this edition in the British Museum.

[3] See W. Carew Hazlitt's *Schools and Schoolmasters*, 1888, p. 53.

[4] Nicolson, *Scottish Historical Library*, p. 43. London, 1736, fol. The MS. is in the Advocates' Library.

[5] See *Maitland Club Miscellany*, II., p. 43, for payments to Hume, 1621-33, as Schoolmaster of Dunbar.

[6] As to Hume and his grammar, see M'Crie, *Life of Andrew Melville*, pp. 382, 383, 473, Edinb., 1856, 8vo. There is a copy in the library of the University of Glasgow.

[7] On 14th July, 1630, the Town Council of Aberdeen paid £40 Scots to Mr David Wedderburne his charges in going to Edinburgh and appearing before the Privy Council "anent the new grammar set out be Mr Alexander Hume." *Extracts from the Records of the Burgh of Aberdeen*, 1625-42, p. 30, Edinburgh, 1871.

9. Linguae latinae Exercitatio.

Edinb. (Andreas Hart), 1620, 12mo,[1]

by Ludovicus Vives, "gloria ingenii, eruditionis atque eloquentiae insignis," a book which passed through several editions upon the continent;[2] and was reprinted at Edinburgh in 1644[3] and 1657.

10. Rudimenta Grammaticae Latinae.

London, 1624, 12mo,

by Joannes Leochaeus, *i.e.*, John Leech, M.A., of King's College, Aberdeen, tutor to James Murray, Earl of Annandale, for whose use it was composed.[4]

11. Short Introduction to Grammar.

Aberdeen, 1632, 8vo.

Again *Ib.*, 1633, 1637.[5]

Institutiones Grammaticae.

Aberdeen, 1634, and again 1635, 8vo.[6]

These were both by David Wedderburne, master of the Grammar School of Aberdeen.[7] The earlier volume was patronised by the Convention of Royal Burghs who, in 1633, ordained that it "be used by all Schoolmasters and taught in

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[1] Chalmers' copy is now in the British Museum.

[2] There were editions, Coloniae, 1538, 8vo; Basil, 1541, 8vo; *Lugd*, 1543, 8vo; Romae, 1597, 8vo.

[3] Laing, *Catalogue*, Part II., No. 2043. The edition of 1657 is in the British Museum.

[4] Leech was the author of a rare volume, *Musae priores sive Poematum pars prima*, London, 1620, 8vo. See Irving, *Memoirs of George Buchanan*, p. 14, 2nd edition, Edinb., 1817, 8vo. There were copies in Principal Lee's library. See *Catalogue*, Part I., No. 62; II., No. 1182.

There was a contemporary John Leech, an English schoolmaster, and author of *Booke of Grammar-Questions*, London, 1628, 8vo, second edition.

[5] See Edmond, *Aberdeen Printers*, p. 42, who suggests that the date may be a misprint for 1637. See *Ib.* and p. 59. This, however, is a mistake. There is an edition of 1633, a copy of which is in the library of the University of Glasgow, and which is described on the title page as "Editio Secunda."

[6] There was a copy in Principal Lee's library *Catalogue*, Part I., No. 2632; and in Blackwood's *Catalogue*, No. 11,585, Edinb., 1809, 8vo.

[7] On 1st December, 1630, the Town Council of Aberdeen despatched the author to Edinburgh to obtain the approval of the Grammar by the Privy Council, and allowed him £100 Scots for his expenses. On 30th March, 1631, he had a grant of 100 merks Scots "to help to defray the greit charges quhairin he hes bein drawin be his long attendance in Edinburgh, Sanctandrews and Glasgow, in the purches and obteining of the councel and clergies of this kingdome, thair approbatioun and allowance to his new reformed grammer." On 12th September, 1632, they allowed 200 merks further on account of the expenses of printing in recognition of the dedication of the Grammar to the Magistrates and Council. *Extracts from the Records of the Burgh of Aberdeen*, 1625, 1642, pp. 32, 35, 50. Edinburgh, 1871.

schools within the Kingdom."[1] The burgh of Dumbarton ordered 40 copies and paid for the Grammars 4 shillings Scots or 4d. Sterling apiece, and for the Rudiments one half of this sum.[2]

Wedderburne's grammar seems to have held its own for the next sixty years, as the Town Council of Edinburgh in 1696 recommend its use.[3]

12. Grammatica Latina ex Despauterio et Linacro praecipue concinnita.

Edinb., 1632, 8vo,

by Robert Williamson, master of the Grammar School of Cupar.

This it is said was an improved version of another grammar published by him in 1625.[4]

13. Quaestiones grammaticae.

Edinb., 1660, 8vo,[5]

by George Lightbody.

There was an earlier edition, Edinb., 1628, 8vo, of which there is a copy in the library of the University of Edinburgh.

14. Grammatica facilis.

Glasgow, 1674, 8vo,

by James Kirkwood. This grammar and other works by Kirkwood will be noticed more particularly hereafter.

15. Grammatica Latina.

Edin., 1679, 8vo,

by Patrick Dykes of Perth, schoolmaster first at Doune and then at Dunfermline.[6]

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[1] *Records of the Convention of Royal Burghs*, IV., p. 532, p. 527, Edinburgh, 1880, 4to. Irving, *History of Dumbartonshire*, p. 503, Dumbarton, 1860, 4to. *Extracts from the Records of the Burgh of Peebles*, pp. 373, 374, Glasgow, 1872, 4to. *Extracts from the Records of the Burgh of Stirling*, p. 171, Glasgow, 1887, 4to. There was a copy in David Laing's library, *Catalogue*, Part I., No. 3577.

[2] Irving, supra.

[3] David Wedderburne wrote a commentary on Persius;—*Persius Enucleatus sive Commentarius . . . in Persium . . .* which was published after his death by Daniel Elzevir, Amst., 1664, 12mo. There is a short prefatory note by his brother Alexander Wedderburne.

[4] See Chalmers' *Catalogue*, Part III., No. 385.

[5] There was a copy in Ruddiman's library *Bibliotheca Romana*, p. 62, and one in David Laing's library, *Catalogue*, Part II., No. 2294.

[6] See Henderson, *Annals of Dunfermline*, p. 373, Glasgow, 1879, 4to.

A second edition appeared in 1685.[1]

16. Nova & artificiosa Methodus docendi linguam Latinam.
London, 1687, 4to,

by John Monro, a Regent in the University of St. Andrews[2] It is dedicated to Sir Andrew Forrester, to whose eldest son he had been tutor.

A third adition appeared at Edinburgh in 1711 under the editorship of John Forrest, schoolmaster, Leith. It is an excellent grammar.

17. Paedomathes seu Manductio grammaticalis.
London, 1689, 12mo,

by George Gordon.

18. Institutio Grammatica.
London, 1690, 8vo,[3]

by Andrew Monro, M.A.

Dedicated to William III.

The Rudiments are in English. The Etymology, Syntax and Prosody are in Latin.

19. Mystagogus Lillianus: or a practical comment upon *Lilly's* accidence, according to the most celebrated grammarians, both ancient and modern. . . .
London, 1712, 8vo,[4]
pp. 60,

by William Hamilton, Schoolmaster in Burre Street, below the Tower.

20. Dux Verbalis: or a Resolution of Lilly's Conjugations, into a more plain and easie Method, even according to his own Scheme.
London, 1712, 8vo,

by William Hamilton.

This is an Appendix to the *Mystagogus Lillianus.*

Ruddiman gives 1692 as the date of publication. There is, however, no indication in the edition of 1712 that there had been an earlier publication.

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[1] A copy of the edition of 1679 was in Principal Lee's library. *Catalogue*, Part I., No 770. A copy of the edition of 1685 appeared in William Blackwood's *Catalogue*, No. 11,406. Edin., 1809, 8vo. I have a copy of this edition.

[2] See Chalmers, *Life of Thomas Ruddiman*, p. 144.

[3] There is a copy in the Advocates' Library, Edinburgh. There was one in David Laing's library, *Catalogue*, Part II., No 2031.

[4] There are copies in the Advocates' Library and British Museum.

These works, Nos. 17, 18, 19 and 20, are included by Ruddiman in his list; but although Gordon, Monro and Hamilton were Scotsmen, their works were prepared for use in England and seem never to have circulated in Scotland.

21. Syntaxis vernacula; vel nova et facilis methodus compositionis; compiled for translating the English into Latin, and è contra.

Edinb., 1686, 8vo.
Again 1691 and 1696, 4to,

by Robert Blau, M.A., schoolmaster of Calder, and afterwards (1678) one of the masters of the High School of Edinburgh. He was deposed in 1685.

He also wrote *Vocabularium duplex seu Fraus elusa*, Edinb., 1686 and 1698, 8vo; and *Rudimenta Etymologiae & Syntaxeos, or a new and easy method of teaching the Latin tongue.* Edinb., 1701, 8vo.

He had a privilege from the Privy Council in 1686 for printing the *Vocabularium* and some other works. He is "said to have acted as a spy, and to have rendered himself otherwise subservient to the despotic measures of the government to which he owed his licence."[1]

22. Institutiones Grammaticae succinctae ac faciles.

Edin., 1701, 8vo,

by William Sanders, professor of Mathematics at St. Andrews and afterwards Schoolmaster at Perth;[2] and brother of our Glasgow printer Robert Sanders.

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[1] Lee, *Memorial*, p. 153. See *Miscellany Maitland Club*, II. pp. 227-230.

[2] He was also the author of (1) *Theses philosophicae quas . . . adolescentes aliquot Collegii Leonardini alumni . . . propugnabunt.* Glascuae, 1674, 4to; (2) *Elementa Geometriae*, *Ib.*, 1686, 8vo; and (3) of an English Grammar. The last two were advertised in the *Edinburgh Gazette.* No. 388, 7 December, 1702.

On 1st October, 1730, the Merchants' House of Glasgow granted £24 Scots per annum, being £6 quarterly to "Anna Sanders, Relict of Mr William Sanders, Professor of y^e Mathematicks in y^e University of St. Andrews and Uncle to Robert Sanders of Auldhouse deceast." *View of the Merchants' House of Glasgow*, p. 161. Robert Sanders of Auldhouse was the son of Robert Sanders, the printer, and was, like his father, a printer and bookseller in Glasgow. "He was exceedingly disobliged by his relations and so put all he had by them." He left his property to the Merchants' House. Wodrow, *Analecta*, IV., p. 102. Of John Sanders, anno 1611, see *Miscellany of the Maitland Club*, I., p. 336, sqq.

23. New method of teaching the Latin Tongue, in such a natural order, as a child may learn that language more speedily than any other Grammar yet extant.

Kirkbride, 1711, 8vo,[1]

by John Hunter, Minister of Ayr.

It was appended to a new edition of Dr Thomas Harrison's *Topica Sacra.*

24. Grammar made easy; containing Despauter's *Grammar return'd* . . . Together with a new method of teaching Latin by ten English particles. To which is added a *Critical Syntax.*

Edin., 1704, 8vo,[2]

by Thomas Watt, A.M., schoolmaster of Haddington, and afterwards (1709) one of the masters of the High School of Edinburgh. It was repeatedly reprinted.

Watt was the editor of *Vocabulary English and Latin.* Edinburgh. Third Edition, *Ib.*, 1734; Fourth Edition, *Ib.*, 1749. This is a manual of conversation, as well as a vocabulary.

25. Rudiments of the Latin tongue, explaining the terms and rules of Grammar.

Edin., 1714, 12mo,

by Thomas Ruddiman (1674-1747).

This is one of the best known and most useful grammars ever published, and has hardly yet been superseded.

The seventeenth edition appeared in 1769; the twentieth at Glasgow in 1777; another at Glasgow in 1782, and a great number of other editions elsewhere. It was edited by Dr George Chapman of the Grammar School, Dumfries, Glasgow, 1793, 12mo., with a Vocabulary Latin and English; by Dr John Dymock of the Glasgow Grammar School, Glasgow, 1819, 8vo; by Dr John Hunter of the University of St. Andrews, Cupar, 1820, 12mo; by William Mann, Baltimore, 1855, 12mo; and it appeared in Chambers' *Educational Course*, London, 1854 and 1859, 8vo.

It was translated into French by J. à Porte, Minister of the Gospel and Regent of the College of Geneva and published at Geneva in 1742, 8vo.

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[1] There was a copy in David Laing's library, *Catalogue*, Part II., No. 2,031.

[2] The date is 1704 not 1714 as given by Ruddiman.

Ruddiman also wrote a complete grammar:

Grammaticae Latinae Institutiones.
Edinb., 1725-31, 8vo, 2 vols.

It passed through several editions, one of the latest of which was by the eminent philologist, Gottfried Stallbaum, Leipzig, 1823, 8vo, 2 vols.; and with the *Aristarchus* of G. J. Voss served as the foundation of K. L. Schneider's Complete Latin Grammar in 1819.[1]

In 1733 Ruddiman published a *Dissertation upon the way of teaching the Latin tongue* in Love's *Animadversions upon Trotter's Grammar*, to be mentioned presently.

26. Short Introduction to the Latin Grammar.
Edin., 1714, 8vo,

by James Bayne, Master of the Grammar School of Dunfermline.[2]

27. A plain and easy Latin Grammar.
Glasgow, 1721, 8vo,

by George Crawford, Schoolmaster at Mauchline.

28. Grammaticae Latinae Compendium.
Edinb., 1732 and 1733, 8vo,

by Robert Trotter, Schoolmaster, Dumfries.

Animadversions upon this grammar were published by John Love, Schoolmaster of Dumbarton, afterwards one of the masters of the High School of Edinburgh,[3] Edinburgh, 1733, 8vo.[4] To these was added Ruddiman's *Dissertation upon the way of teaching the Latin tongue.*

29. Index to the Etymology of Mr. Ruddiman's Grammar.
Glasgow, 1733, 8vo,

by James Purdie, Master of the Grammar School of Glasgow.

30. An Introduction to Latin Syntax; or an Exemplification of the Rules of Construction, as delivered in Mr. Ruddiman's Rudiments.
Edinburgh, 1755, 8vo,

by John Mair, A.M., Schoolmaster first at Ayr, and subsequently Rector of the Academy at Perth.

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[1] Burstan, *Geschichte der classischen Philologie in Deutschland*, p. 782. München, 1883, 8vo.

[2] See Henderson, *Annals of Dunfermline*, p. 42.

[3] As to Love, See Chambers' *Life of Thomas Ruddimon*, pp. 135, 144.

[4] As to these *Animadversions*, See Chalmers, *supra*, p. 134.

Mair's *Introduction* was very popular and passed through numerous editions. Until quite recently it was a standard text-book in every Scottish school.

Mair was an industrious author. He published editions of Cordery's *Colloquies*, Cæsar, and Sallust, all with literal translations; and, besides works on Book-keeping, Geography, and Arithmetic, wrote:—

The Tyro's Dictionary, Latin and English.
Edinburgh, 1760, 8vo,

which was at one time in general use; and of which an edition by George Ferguson, Professor of Humanity in King's College, Aberdeen, appeared in 1846.

A Radical Vocabulary, Latin and English.
Edinburgh, 1772, 8vo,

which was also a popular School book for many years.

31. The Rudiments of the Latin Tongue.
Edinburgh, 1758, 8vo,

by James Barclay, A.M., Rector of the Grammar School of Dalkeith (1750-65).

pp. xii. + 176.

Dedicated to the young Duke of Buccleuch.

Ruddiman's *Rudiments* are unexceptionable, so far as they go, but the author thinks that they are too brief, and some things are omitted which might have been included with advantage.

Mr Barclay was one of the best schoolmasters and grammarians in Scotland;[1] and had[2] amongst his pupils Alexander Wedderburne, afterwards Baron Loughborough, Earl of Rosslyn, and Lord Chancellor.

The course of instruction laid down, in 1597, for the High School of Edinburgh was:—In the First or Junior class the Dunbar *Rudiments*, with the *Colloquies* of Cordery; and on Sunday the *Catechesis Palatinus*. The Second class were taught the rules of the first part of Pelisso, wrote exercises or versions thrice a week,

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[1] Alexander Carlyle, *Autobiography*, p. 353. Edinburgh, 1861, 8vo; Campbell, *Lives of the Lord Chancellors*, vi., p. 5. London, 1847, 8vo.
He was one of the masters of the High School of Edinburgh, 1742-50. He died 5th June, 1765. One of his daughters married John Ballantyne, merchant, Kelso, whose sons James and John Ballantyne were afterwards associated with Sir Walter Scott.

[2] He is said to have foretold Wedderburne's future eminence. *Glasgow Courier*, 23rd February, 1793.

and read the *Tristia* of Ovid and Cicero's *Familiar Epistles.* On Sunday they committed to memory the Catechism "lately set out in Latin." In the Third class they were instructed in the second part of Pelisso, the *Syntaxis* of Erasmus, Ovid's *Metamorphoses,* Terence; on Sunday Buchanan's *Psalms.* In the Fourth or highest class the third part of Pelisso with Buchanan's *Prosodia,* Linacre *On the construction of the Latin Language,* Virgil, Sallust, Cæsar's *Commentaries,* Florus, Ovid's *Epistles;* on Sunday Buchanan's "heroic" *Psalms.*[1]

Similar arrangements were made for the other Grammar Schools of the country, and all were altered from time to time. Each school selected its own grammar. Preference was given to one Grammar at one time and then to another at a later period, but, in so far as concerned Latin Grammars, the Dunbar Rudiments was the most popular.

The Account Book of Sir James Foulis, of Ravelston, gives a good idea of a schoolboy's outfit in the latter part of the seventeenth century :—

> 17th June, 1672. "For a Corderius, Rudiments, Gramar and Latin Catechise to Archie, £1 13s. 4d."
>
> 6th January, 1673. "For Isop's fables in Scots to Archie w^t the cuts, £1 7s."
>
> 28th February, 1681. "For a Lucan and Floras to Geordie, £1 9s. od."
>
> 16th March, 1681. "For Livius Ora^o^ns to Geordie, £1 8s. od."
>
> 13th December, 1689. To Mr Laurence Dundas to pay for a Floras to Willie, a Gramer to Sandie, and a paper booke to him, and Proverbs to Adie, £1 12s. od."[2]

While there was no compulsory uniformity, the course of study and method of teaching were pretty much the same in all schools; and the actual number of different grammars, vocabularies and reading books employed was not very large. The greater part of all the books used were printed in Edinburgh; a few in Aberdeen and other towns. Glasgow also had its share, and my object in the following paper is to describe the Grammars and other school books issued at Glasgow in the seventeenth and the

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[1] Steven, *History of the High School of Edinburgh,* p. 34. Edinburgh, 1849, 8vo ; Appendix, p. 24.

[2] *The Account Book of Sir John Foulis, of Ravelston,* pp. 6, 14, 77, 79, 116 (Scottish History Society). The sums are of course in Scots money.

early part of the eighteenth centuries. A printing press was set up in Glasgow only in 1638, and for a long time there was but one printer in the city, so that the production of books of any kind was necessarily limited.

There were many complaints in the seventeenth century of the inaccuracy of the printing of school books. Great difficulties, it is said, were experienced both by teachers and learners "from the scandalously erroneous printing of all manner of school-books whatsoever, which are printed here in Scotland, whether Latin or English, even from the Shorter Catechism to the classic authors and grammar upwards."[1] This is a somewhat exaggerated statement. School books were sold at a cheap price and were consequently rather rough, but they were mostly handy, serviceable volumes.

As is well-known, old school books of all descriptions are exceedingly difficult to find. Many have altogether disappeared, and of others a few copies only are in existence. It is only recently that public libraries have thought it worth their while to collect them systematically, and as yet there is no collection of any great extent except that in the British Museum, and it is very imperfect.

Glasgow school books are particularly rare, and many I know only from Catalogues.

I propose to deal with them under the following heads :—

I. Latin Grammars and Introductory Works.
   Latin Vocabularies.
   Latin Reading Books.
   Roman Antiquities.
   School Plays.
II. Greek Grammars.
III. Hebrew Grammars.
IV. French Grammars.
V. English Grammars.
   English Dictionaries.
VI. Arithmetical Books.

[1] *Letter to a Member of the General Assembly concerning the education of children*, quoted by Dr Lee, *Memorial*, p. 151.

I. Latin Grammars and Introductory Works.

1. Onomasticon Poeticum . . . Thoma Jacchaeo Caledonio authore.

Edinburgi, Excudebat Robertus Waldegraue, Typographus, Regiae Maiestatis, 1592. Title page + 10 + 150 pp., 4to. Italic letter.

Thomas Jack, the author, had been Master of the Grammar School of Glasgow. He was now Minister of Eastwood, or as he translates it, *Sylva*, vulgo dicta, *Orientalis.* The book is dedicated to James, eldest son of Claud Hamilton, Commendator of Paisley, who, along with John Graham, a younger son of the Marquis of Montrose, had been his pupils at Glasgow. In a commendatory poem by Robert Rollock, Principal of the University of Edinburgh, he refers to him as "praeceptor ille olim meus Iacchaeus," from which it appears that he likewise had been Jack's pupil. There are other commendatory poems by Hercules Rollock, head master of the High School of Edinburgh; Patrick Sharp, Jack's son-in-law and successor in the Grammar School of Glasgow, and then Principal of the University; Andrew, Melville and Sir Thomas Craig. There is also a poem and a letter by Hadrian Damman, of Bistervelt, who had been appointed Professor of Law in the University of Edinburgh, but lectured on Latin, and who is here styled Regius Professor of History.

The *Onomasticon* [1] is an alphabetical dictionary of proper names

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[1] Other works somewhat of the same character are : —

The *Epithetorum opus* and *Officina* of Joannes Ravisius, known as *Textor*, [*i.e.*, Jean Tixier of Ravisi] of the College of Navarre (*d* 1524), both of which passed through numerous editions, and both of which were abridged and were also issued, like Bagster's Bibles, with wide margins or interleaved for additions.

Buchler, *Thesaurus poeticus.*

Fabricius, *De Ephithetis praeceptiunculis.*

The *Prosodia* of Henrich Smet a Leda (1537-1614), Physician, Poet and Scholar. The *Prosodia* is a Dictionary of Quantities shewn by lines from the Poets. It was first published in 1599. The twelfth edition appeared in 1628, 8vo, and the fourteenth in 1635, 8vo, both at London.

There is also the *Lusus poeticus* of John Langston, teacher of a private Grammar School near Spittlefields, 1675, 8vo. This is a collection of the more eminent sayings of the Latin poets for the service of youth in capping of verses, alphabetically arranged.

occurring in the classics with references to the sources, and is written in hexameters. The following are specimens :—

Britannia. Insula in Arctoo septem subjecta trioni.
Ovid, 2 Amo., Met. 5.
Oceano, Europae vicina, Britannia dives,
Clau. Bello. Get.
Angli habitant Austrum, Boream gens Martia Scoti :
Luc. 2.
Britanni. Vtrosq ; inde ferunt divisos urbe Britannos.
Verg. in Buc.
*   *   *   *
Scoti. Gaudet magnanimis Arctoa Britannia Scotis :
Clau. Pan., 7 de Bello. Getico
Hi nulli imperio externo parere coacti :
(Caesaribus reliquus fermè dum paruit orbis),
Nulla iuga agnôrunt : servit quibus ultimis Thule,
Sta. Sil. 3.
Et quas vix numeres regiones aequore cinctae.
*   *   *   *
Thule. Magnanimis Thule subiecta est insula Scotis,
Sene. Tra. 7.
Quam Maro Caesaribus magnum parere putabat :
Verg. I. Geor.
Orcadicos ultra fines haec tendit in Arcton.
Claud de Bello Get. Iu. 15.

The work, he says, was commenced when he was master of the Grammar School. Andrew Melville encouraged him to carry it on, and George Buchanan revised it.[1]

2. Georgii Buchanani Scoti De Prosodia Libellus.
Glasguae, Robert Sanders, 1667.

This I have not seen, and only know it from David Laing's Catalogue.[2]

Buchanan's tract on Prosody was published by Waldegrave at Edinburgh in 1595, by Andro Hart in 1621,[3] and was often reprinted. There are Edinburgh editions of 1600,[4] 1640, 1645,

[1] See Dedication. cf. Irving, *Memoirs of George Buchanan*, p. 238, 2nd ed., Edinb., 1817, 8vo.

[2] Part II , No. 476.

[3] The book is not dated. There is a copy in the library of the University of Edinburgh. This is no doubt the copy which appeared in Blackwood's *Catalogue* of 1809. See *supra* p. 8.

[4] There was a copy in the Harleian Library, *Catalogus Bibliothecae Harleianae*, II., No. 15,530.

1660, 1678, 1686, 1689 and 1699 appended to Despauter's Grammar.

It is also in the two editions of Buchanan's collected Works, the one by Ruddiman, Edinburgh, 1715, fol, 2 vol.; the other by Burmann, Lugd. Bat., 1725, 4to, 2 vol.

3. Grammatica facilis seu nova, & artificiosa Methodus docendi linguam Latinam . . . Authore Jacobo Kirkwodo. Glasguae, Excudebat Robertus Sanders, Civitatis & Universitatus Typographus. 1674, 8vo. A1 – L, 8. Title page + 13 pages, not numbered + 169 + 7 not numbered.[1]

James Kirkwood, "vir perspicacis ac subacti ingenii,"[2] the most eminent grammarian of his time, was born in the neighbourhood of Dunbar. There is no information as to where he was educated, but in 1665 he was an unsuccessful candidate for the professorship of Humanity in the University of Edinburgh.[3] At a later period he acted as tutor or governor to Charles, Lord Bruce, the eldest son of Alexander, second Earl of Kincardine.[4] He accompanied him when he was a student at the University of Glasgow, 1672-74; and resided with him in the house of Dr Gilbert Burnet, Professor of Theology, afterwards the famous Bishop of Salisbury. During this period he composed this grammar for the benefit of his pupil, to whom it was dedicated. He mentions (p. 17) the ease with which the latter learned Latin, and his facility in speaking it, which he ascribes to the excellence of his own new method of instruction. The dedication is dated from Culross, the Earl of Kincardine's seat, the 15th of May, 1674, and the book was published shortly afterwards.

There are prefixed, according to the fashion of the day, a large number of commendatory poems and letters. The poems are by John Anderson, an undermaster or doctor of the Grammar

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[1] Since this paper was written Mr Aldis' *List of Books printed in Scotland before 1700*, has appeared. He has no reference to a copy in any of the public libraries. My description is from a copy in my own possession. Mr Aldis enters two editions under the date 1674. If there were two, the second must have been pirated. See *infra* p. 25.

[2] Dykes, *Grammatica Latina*, Testimonial by the Presbytery of Dunblane. Edin., 1685, 8vo.

[3] Dalzel, *History of the University of Edinburgh*, II., p. 367, and Index, where he is identified, Edinburgh, 1862, 8vo.

[4] Ninian Paterson addresses an Epigram to him. *Epigrammatum Libri Octo*, Lib. ii., p. 18, see also Lib. iii., Ep. 8, Edinburgh, 1678, 12mo.

School of Glasgow; Patrick Johnston, Master of the School of Hamilton; and Ninian Paterson the well-known epigrammatist, who was then parish minister of Smallholm.[1] The first of the prose contributions is by Professor Gilbert Burnet, who congratulates Scotland on having formerly produced the greatest writer and poet since the age of Augustus, and having now produced the most learned compiler of a grammar. Francis Kincaid, the rector of the Grammar School, praises the conciseness and perspicuity of the work, and the excellence of its method. Then follow testimonials by Gasper Kelly, minister of Dunblane; Robert Cunningham, physican to the King (who translates the author's name into Jacobus Templo-Sylvius); William Broun, master of the Grammar School of Stirling; James Pillans one of the Regents in the University of Edinburgh; William Blair, Thomas Nicolson, John Trane and John Boyd, the four Regents or Professors of philosophy in the University of Glasgow; the well-known George Sinclair, formerly Professor of mathematics in the University of Glasgow and then head-master of the School at Leith; and his brother John Sinclair, the minister of Ormistoun; David Skeoch, head-master of the Grammar School of Linlithgow; William Skene, schoolmaster at Haddington; the celebrated Glasgow physician, Dr Matthew Brisbane; the Rev. Alexander Strang, head-master of the Cannongate Grammar School; and Arthur Millar, head-master of Dumbarton Grammar School. The last was by Mr William Cumming, Professor of Humanity in the University of Edinburgh, and then Governor to Lord Lorne, and is addressed to all doctors, schoolmasters and other teachers of youth in Scotland. John Sinclair's epistle is addressed to Professor Cumming and approves of his remarks. Sinclair draws attention to the carelessness then existing in reading and pronouncing Latin, and mentions that it was very different in his younger days, thirty or forty years before, when neither teacher nor pupil made such mistakes.

The Grammar, "eruditum illud Grammaticae monumentum,"[2] deserved the praise it got. It is a compact, useful and well arranged book; and contains some sensible remarks on the method of using it. The author gives (p. 22) an injunction,

[1] See also his *Epigrammata, supra*, Lib. iii., Ep. 11.

[2] Dykes, *Grammatica Latina*, Testimonial of the Presbytery of Dunblane, Edin., 1685, 8vo. Gasper Kelly, *supra*, was one of those who signed this Testimonial.

which is not always observed in these days of interminable written examinations :—

> "Let no question be put to the scholars, which a learned man and one well skilled in the rules of grammar cannot answer."

He deals (pp. 24, 25,) with the question whether a Latin grammar should be written in Latin or in the vernacular. He had been urged by many to use English, but all the schoolmasters whom he had consulted were against this, and, although his own view was in favour of English, he yielded to the professional opinion.[1]

Lord Kelvin used to insist, by way of parenthesis in the middle of an exposition of Newton's Laws or the like, upon the absurdity of learning to read Latin without the use of a translation. Kirkwood was somewhat of the same mind. To acquire a vocabulary he recommends the frequent perusal of small books in Latin and English, as for example Charles Hoole's translation of the *Colloquia* of Cordery, his *Pueriles Confabulatiunculae*[2] and John Clark's *Sermones Pueriles*. Proverbs and choice phrases should be committed to memory[3]; and it ought to be the duty of the teacher to keep in advance of his class and have everything prepared for them.

Wall diagrams, we imagine, are a modern invention, but this is not so. Kirkwood points out (p. 28) that the whole scheme of Latin Grammar arranged in Tables should be hung upon the walls of the schoolroom. The various plates should be changed once a month for, as he explains, if anything is kept before the eyes for too long a time, it is not observed or we grow sick of looking at it.

It is no use, he remarks (p. 27), to read history or poetry unless the pupils have some knowledge of geography and astronomy. All schools, therefore, or at least the more frequented, should be supplied with maps and globes. This we know was his own

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[1] The criticisms on the Grammar after it was published were very various. "Quot capita, tot reperis sententias. Hic omnia laudat: ille quaedam carpit: alius multa desiderat." Kirkwood *Prima Pars Grammaticae in metrum redacta*. Epistola. Edin., 1675.

[2] John Brinsley made the same suggestion. *Consolation for our Grammar Schooles*, p. 61.

[3] He may have had in view *Carminum Proverbialium . . . Loci Communes*. London, 1588, 1595, 1603, 12mo., which must have been in use in Scotland, as an edition was issued at Edinburgh in 1701, 12mo., which is an exact reprint of the original, with the prefatory verses, "S.A.I. ad Emptorem."

The *Catonis Disticha* and *Dicta Sapientum* were also in common use in all Scottish Schools, as will be afterwards explained.

practice. In his house in Linlithgow he had "many fine maps and carts (above 40) all well illuminated, of the newest and best sort; a great number of rare pictures of famous and learned men; many curious Cuts of the historical part of the Scriptures; several Chronological Tables, shewing the memorable persons and actions from the Creation to our days, with many other rare inventions of that kind. These, he adds, were "not only an ornament to his house, but of great use to his scholars and others." [1]

Kirkwood seems to have been a most industrious man. Eighteen months after the publication of the *Grammatica facilis* he issued:—

Prima pars grammaticae in metrum redacta.
Edinburgi, 1675, 12mo,
pp. 77 + Privilegium 1 page + Title page
+ 12 pages not numbered.

The dedication to the Provost and Magistrates of Linlithgow is dated 1st November, 1675.

He apologises for the rudeness of his verses, but says that such things, as C, L, M, T, U, Sb, Sp, Bs, Ps, Fex, Ceps, Er, Ir, Ur, Us, Um, Eus, Os, On, are hard to handle. He insists that boys should not be troubled with too many minutiae of grammar; but if they were expected to learn the author's verses they would have a hard and wearisome task.

The practice of embodying the Latin grammar in a series of mnemonic verses was a relic of the Middle Ages. The example was set by Alexander Dolesius or Gallus, otherwise de Villa Dei, who flourished about the year 1244, and composed *Doctrinale seu Grammatica latina*, in leonine verse.[2] It was printed as early as 1470, and ran through a great number of editions,[3] three of which

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[1] *The History of the Twenty-Seven Gods of Linlithgow*, p. 31, Edinburgh, 1711, 4to.

In 1611, Mr John Johnstoun, Professor at St Andrews, author of the *Inscriptiones historicae Regum Scotorum*, Amst., 1602, made special bequests, of his "haill broddit mappes," to the Library of St Andrews, and of his "louse mappes unbroddit" to a friend. Testament of Mr John Johnstoun, *Miscellany of the Maitland Club*, I. pp. 338, 345. Andrew Hay of Craignethan, when retiring on 26th August, 1659, to prepare for the communion, "did also read a little whyle upon Samson s carts [*i.e.*, maps] to see the places where the insurrection had been in Ingland." *Diary*, p. 118, Edinburgh, 1901, 8vo.

[2] Walch, *Historia critica Latinae linguae*, p. 240, Lipsiae, 1761, 8vo; Wadding *Bibliotheca Scriptorum Ordinis Minorum*, p. 9, Romae, 1650, fol. cf. Thurot, *Notices et Extraits des MSS.* xxii. (1869), 2e *Pt.*, pp. 28 *sqq.*, 98 *sqq.*; Littré, *Histoire littéraire de la France*, xxii. (1852) p. 69, *sqq.*

[3] According to De Bure, *Bibliographie Instructive*, No. 2275, the edition, Venice, 1473, fol., is the only one of interest to collectors.

were by Pynson in 1505, 1513, and 1516. Several commentaries on it appeared, one of which was by John Vaus of Aberdeen, to whom reference has already been made. Jean Despauter also wrote notes upon it, or rather upon the commentary of Hermann Torrentinus.[1] According to Paulsen, this grammar, as taught and explained, could be made a suitable instrument for teaching[2]; but the same could be said of any book however defective. Everything depended upon the teacher. In 1499 there was published at Strasburg a grammar, in hexameter verse, by Peter Helias, with a commentary in prose by Johann Somerfeldt.[3] Many others followed and in his poetical attempts James Kirkwood was only walking in the well-trodden path of custom.

A French metrical version of the elementary Latin Grammar according to Despauter appeared in 1656.[4]

There was no general copyright in those times. Each book had to be separately protected, and there is prefixed to this work a Privilege by the Privy Council granting to the author the exclusive privilege of printing his Grammar for the space of nineteen years. It is mentioned that it had already been reprinted without his authority "with so many gross errors that the same would seem to be done of purpose to put a publick affront upon the author."[5]

Next year, 1676, there appeared:—

> Secunda pars Grammaticae, jam delineata secumdum sententiam *Plurium*, sicuti promissum est in epistola *D. D. Cuminii. Editio secunda.* Authore Jacobo Kirkwodo.
> Edinburgi, 1676, 12mo,
> pp. 75.

This is an enlarged and improved version of Part II. of the *Grammatica facilis.* It explains (p. 73) Anglicisms or, as he says they should rather be called, Scotticisms; *Ille non est apud Scholam* is bad Latin for *Ille non est discipulus,* or *non dat operam literis,* or *non militat sub ferula praeceptoris nostri: Clama supra illum* should be *Voca illum.*

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[1] *Hermanni Torrentini . . . in primam partem Alexandri Galli, Theopagitae, Commentarius, Johann. Despauterii . . . annotationibus.* Sanct. Ubiorum Colonia, 1522, 8vo. Of this I have a copy.

[2] Paulsen, *Geschichte des gelehrten Unterrichts,* p. 25, Leipzig, 1885.

[3] Walch, *supra* p. 240.

[4] La Porte française en verse burlesque, pour faciliter l'entrée à la langue latine suivant l'ordre de toutes les règles du Despautere latin, ouverte par le sieur Agatomphile, Chalonnois, Lyon, 1656, 12mo.

[5] See *supra* p. 21.

There was published at the same time *Tertia Pars Grammaticae*, pp. 46, with a separate title page, similar to that of Part II. and the *Quarta Pars*, pp. 8.

These are much the same as in the *Grammatica facilis*.

Along with these was issued :—

> All the Examples, both words and sentences of the first Part of Grammar translated into English. By J. K.
>
> Edinburgh, 1676, 12mo,
> pp. 68 + Title page + 6 pp. not numbered.

This is a Vocabulary to the metrical version of Part I. arranged according to the order in which the words occur. Nearly all the renderings are good English. Comparatively few are Scotch. Amongst the latter are—

Cardo,	a door crook.
Harpago,	a cleik.
Papaver,	a poppy or chesboul.[1]
Dos,	tocher-good.
Subscus,	a joyning or fastening of boords together, called by Artificers a culver-tail.
Stips,	a penny, such as is given to beggars.
Thorax,	the breast or bulk of a man.[3]
Talpa,	a mole or moodiwarpt.
Vas, vadis,	a cautioner.
Vomis,	the sock of a plough.
Buris,	the stilt of a plough.
Olus,	cail or pot herbs.
Repotia,	after-Drinking, as on the Day after Marriage.
Scopae,	a besom, a brush.
Colus,	a distaff or rock.
Praecino,	to sing before, or (as in use to speak) to take up the Psalm.
Gruo,	to cruncle like a crane.
Forma viros neglecta decet,	a careless way of busking becometh men ; or men ought not to be too nice in their apparel.

[1] "Quhair that he gat ony chasbollis that greu hie, he straik the heidis from them." *The Complaynt of Scotland*, XI. 94.

[2] *i.e.*, the modern "dovetail."

[3] "The boulke, called in Latyn *thorax*, which conteigneth the brest, the stomake, and entrayles." Elyot (1533) *The Castel of Helth*, 89.

The Grammar was again published in London in 1677:—

Jacobi Kirkwodi Grammatica delineata, secundum sententiam *Plurium*, sicuti promissum est in Epistola D. D. Cuminii.
Londini, 1677, 8vo,
pp. 149. The examples in English follow, 30 pp.

Though printed in London "it was to be sold in Edinburgh at a very easie rate by Henry Leslie, at the sign of the Blew Bible over against Blackfriars Wynde."

The testimonies of divers learned men were printed in a few copies.

This is a reprint of the Edinburgh edition of 1676.

The number of copies of an edition of a book at this period is a matter as to which there is little information, but this throws some light upon it. The edition must have been a large one, as in 1689 the author had on hand 1,800 copies in sheets.[1]

In May, 1674, Kirkwood was invited by Sir Robert Miln, of Barntoun, Provost of Linlithgow, to accept the position of Master of the Burgh School. He had other offers of promotion, but in January, 1675, accepted that of Linlithgow at a salary of 400 Merks (*i.e.*, £266 13s. 4d. Scots, or £22 4s. 6d. Stg.), an advance of 100 merks upon that of his predecessor, which again had been raised by a similar amount in 1652,[2] and to hold office *ad vitam aut culpam*. He entered upon office at Candlemas, 1675, the day after his predecessor had received his Candlemas offering.[3]

Everything went well for a time. The school-master married Goletine Van Beest, a Dutch lady, with whom he probably became acquainted when at Culross. Mrs Kirkwood was well connected; presumably she was a companion or waiting woman of the Countess of Kincardine, Veronica van Arsan, daughter of Corneille van Somelsdyk, Lord of Somelsdyk in Holland.[4] Her brother was an officer in the English army, rising to the rank of Lieutenant Colonel.[5] She had a marriage portion which was apparently of some value as she and her husband seem to have lived comfortably. The magistrates built "the best house in Scotland for their schoolmaster"[6] and the schoolmaster "had the best

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[1] *The Twenty-Seven Gods*, p. 31.

[2] Grant, *Burgh Schools of Scotland*, p. 547.

[3] *The Twenty-Seven Gods*, pp. 3, 15.

[4] Cumming Bruce, *Family Records of the Bruces and Cumyns*, p. 302. Edinburgh, 1870, 4to.

[5] *The Twenty-Seven Gods*, p. 27. [6] *Ib.*, p. 32.

furniture in his house of any of his employ in the Kingdom, having almost all his goods from Holland and London."[1] As was the usual custom, with the masters of large schools, he received boarders, one of whom was John Dalrymple, the eldest surviving son of the first Earl of Stair, and who himself in time became second Earl.

Religious feeling ran high in those times. Mr David Skeoch, his predecessor and one of the approvers of his Grammar, was removed from office "on account of his refusing to abstain from conventicles,"[2] and it was probably because of this that Kirkwood was so particular in stipulating for an *ad vitam aut culpam* appointment. This proved no protection. With the Revolution, presbyterianism gained the day. The greater part of the middle classes were presbyterians, and when the election of magistrates took place in Linlithgow in 1689, the whole or at least the majority belonged to that party. Kirkwood was an episcopalian and was told by the magistrates that he must go with them to the meeting-house, "which was then kept in the Provost's Hall or Kitchen," or be dismissed. Presbyterianism had not yet been formally recognised by the Government, and he declined to acknowledge it until this had been done. This did not satisfy the magistrates; they had him apprehended and cast into prison, turned his wife and children out of the house, and threw his furniture and plenishing into the street. Much litigation ensued which resulted in a decree in favour of the schoolmaster for 4,000 merks Scots, and gave to the world one of Kirkwood's most curious works.

> The History of the Twenty-Seven Gods of Linlithgow, being an extract and true account of a famous Plea betwixt the Town-Council of the said burgh and Mr Kirkwood, Schoolmaster there. Edinburgh, 1711, 4to.

Upon his expulsion he went to Edinburgh and set up a private school, "the greatest that ever was in Edinburgh, and by far the most gainful . . . having about 140 scholars almost all Noblemen and Gentlemen's sons."[3] He refused the professor-

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[1] *The Twenty-Seven Gods*, p. 32.

[2] Grant, *Burgh Schools of Scotland*, p. 268.

[3] *Mr Kirkwood's Plea before the Kirk*, pp. 2, 3, London, 1698, 4to. *The Twenty-Seven Gods*, p. 51.

At this time Mr Gavin Weir had another large private school in Edinburgh. *Memoirs of Mr Thomas Halyburton*, c., iii., p. 32. Glasgow, 1756, 8vo.

ship of Humanity in St Andrews, a call to Duns, another call to be professor of Greek and Latin at Jamestown in Virginia, the mastership of the free school at Kimbolton, and of a free school in Ireland.[1] In the meantime he had complied with the presbyterian form of Church government, and the Countess of Roxburgh having, in 1693, offered him the school of Kelso, he accepted it after considerable hesitation.[2]

He was unfortunate in his appointments. In Kelso he quarrelled with the parish minister and the presbytery which resulted in another very curious publication :—

> Mr Kirkwood's Plea before the Kirk and Civil Judicatories of Scotland.
>
> London, 1698, 4to.

The dispute related to the respective rights of the heritors and Kirk Session in reference to the office of Session Clerk. The heritors claimed that they were entitled to appoint the Schoolmaster, and that of right he was Session Clerk. This the Kirk-Session disputed. The salary of the Session Clerk was only 50 merks Scots, with the casualties of the office. The casualties were the perquisites; sometimes two or three Scots pints of ale when a bridegroom came with his bride to give up their names, and sometimes some nogans of brandy.

The dispute branched out into many questions, and continued for four years, during the whole of which time the school was vacant.

Despauter's grammar was still in extensive use, and a new edition was published at Edinburgh by the Society of Booksellers in 1689. It was not, however, considered satisfactory, and there was a strong desire that it should, if possible, be improved.

When Kirkwood was living in Edinburgh, he was consulted by the Committee of Schools and Colleges as to the books to be read in schools and the grammar to be used.

"What think you of Despauter, said the Viscount Stair? A very unfit Grammar, my Lord, in the case it is, answered I; but by some pains it might be made an excellent one. Several of the members, particularly the Lord Crosrig, desired me to be more plain in that point. Mr Lord *Preses*, said I, if its superfluities were rescinded, the defects supply'd, the intracasies cleared,

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[1] *The Twenty-Seven Gods*, p. 51; *Mr Kirkwood's Plea*, p. 2. [2] *Ib.*

the errors rectified, and the method amended, it might well pass for an excellent Grammar. This motion seemed to please the whole meeting. In short, within two or three days, the Viscount called me to his Chamber, and told me it was the desire of that judicature I should set about the work; for they knew none fitter to do it. Immediately I put hand to pen, and not without very much labour, published Despauter, as now revis'd, dedicating it to their Lordships."[1]

It was published as :—

> Grammatica Despauteriana, cum nova novi generis Glossa; cui subjunguntur singula primae Partis exempla vernacula reddita, Authore Jacobo Kirkwodo, Dumbarensi.
> Edinburgi, 1696, 12mo.

A second edition appeared at Edinburgh in 1700; a third in 1711, and a fourth in 1720.

Kirkwood's work was based upon Despauter's with large importations from his own grammar. While preserving Despauter's form he substitutes memorial verses of his own, and modifies or alters the accompanying explanations. On the whole the alterations are improvements. Some things that might have been altered with advantage are allowed to stand, *e.g.*, *De Nominum generibus:*

> Mobile pro fixo, fixum si subsit, habetur;
> Quod si non subsit fixum, neutri generis sit.

Mobile is used by the old Grammarians as meaning an adjective and *fixum* for a substantive; and the rule is that generally expressed as "An Adjective used substantively is of the gender of the substantive understood, but if no substantive is understood then it is of the neuter gender." The rules for determining the gender of nouns in accordance with their terminations are equally uncouth as given by Alexander Gallus, Despauter or Kirkwood. All that can be said is that they provided the pupil with a *copia verborum.*

Kirkwood adds a Vocabulary of the words used in the first part, just as he had done with his own grammar. The examples are not identical. In his own metrical version he gives as examples of names of women,

> Ut Regina, Soror, Pallas, Catharina, Leæna.

[1] *The Twenty-Seven Gods*, p. 3; Preface to the *Grammatica Despauteriana.* Edin. 1720.

In his version of Despauter, he substitutes Gelecina for Catharina and gives this curious note in the Vocabulary.

> "*Gelecina van Beest* is Mistress *Kirkwood's* Name; that *French*, this *Dutch;* which, being so very pat to the Purpose, he thought it not amiss to insert here, that her's, as well as his Name, may survive when they are dead."

Kirkwood was also the author of *Rhetoricae Compendium*, Edinburgh, 1678, 12mo.[1] It was dedicated to the Duke of Lauderdale.

When Kirkwood died I do not know. He is, however, worthy of being remembered as one of the most accomplished and erudite grammarians of his age. He is one of the few Scotch grammarians quoted by Ruddiman in the *Grammaticae Latinae Institutiones*, who always refers to him as "Kirkwodus noster."

In 1700 the Town Council of Aberdeen made certain regulations for the teaching of grammar in the Grammar School of that burgh, one of which was "that after Dispauter's Grammar is taught, that Kirkwood's Ortheographie and Syntax be learned, with his Tractat *De variis carminum generibus*."[2] In 1710 the Visitors of the School recommended "that all intrants to the said school shall hereafter be taught Kirkwocd's Grammar, which is judged preferable to that of Dispauter."[3] This was somewhat modified by a regulation of next year, which provided "*Primo*, That all intrants to the said Grammar Schools shall hereafter be taught Kirkwood's last edition of Dispauter."[4]

The British Museum Catalogue curiously mixes up the grammarian with his namesake and relative, the minister of Minto, who, having been ejected from his parish in 1681, migrated to England, became rector of Astwick in Bedfordshire, and wrote *An Overture for founding and maintaining Bibliothecks in every Parish throughout the Kingdom* (1699), and *A New Family Book, or the True Interest of Parents*. London, 1693, 12mo.

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[1] There was a copy in David Laing's library *Catalogue*, Part I., No. 1783. Licence of Privy Council, Lee, *Memorial*, p. 157.

[2] *Extracts from the Records of Aberdeen*, p. 329, Burgh Records Society.

[3] *Ib.*, p. 341. [4] *Ib.*, p. 344.

4. Rudimenta Grammatices in gratiam Juventutis Scoticae conscripta. Editio prioribus longè emendatior, & multis in utraq; Grammatices parte adjectis auctior.
Glasguae. Excudebat *Robertus Sanders*, Regiae Majestatis Typographus, *Anno Dom.*, 1693. 8vo, pp. 47.[1]

A neat well-printed edition, on rather coarse strong paper.

The title page is adorned with a cut of the Glasgow Arms with the motto, "Lord let Glasgow flourish through the preaching of Thy Word," above which appear the verses of "the Famous Doctor Main, Professor of Phisick in the University of Glasgow":—

Salmo maris, terraeque arbos,[2] avis aeris urbi
Promittunt quicquid trina elementa ferunt.
Et campana (frequens celebret quod numinis aras
Urbs) superesse polo non peritura docet.
Neve quod indubites sociari aeterna caducis,
Annulus hoc pignus conjugale notat.[3]

This is Andrew Simson's, or the Dunbar, Rudiments, which held the field against all rivals as an elementary grammar until the publication of Ruddiman's Rudiments in 1714. Ruddiman himself informs us that it was in use in his school days,[4] and it was, no doubt, the book from which he learnt grammar. It passed through numerous editions, several of which have wholly disappeared, and of most of the others only one or two copies are known to exist.

Simson's name is not associated with the work in the first or second editions. The third, that of 1607, is said to be by M. A. S., that is Magister Andreas Simson, but so much had the authorship been forgotten that Kirkwood, a Dunbar man, refers to it as "Rudimenta nostra vulgaria, quae ab hisce verbis incipiunt, *Quum literarum*."[5]

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[1] There is a copy in the Glasgow University Library. There was a copy in David Laing's library *Catalogue*, Part IV., No. 1079.

There was an edition, Edinburgh, 1640, 12mo, and another 1670, 12mo, copies of which were in David Laing's library Catalogue, Part III., No. 2017, Part I., No. 1430, Part IV., No. 453. There were other Edinburgh editions in 1693, 1699, 1704, 1709 and 1710, 12mo. I have a copy of the edition of 1704. There was a copy of the 1710 edition in Laing's library *Catalogue*, Part II., No. 2031.

[2] *Sic.* [3] See M'Ure *View of the City of Glasgow*, p. 140; MacVean's edition, p. 118. [4] *Bibliotheca Romana*, p. 61.

[5] Kirkwood, *Grammatica Facilis*, p. 1. It may be, however, that he merely used a common mode of reference.

John Row attributes the authorship to Simson without hesitation. After referring to his removal from Perth to Dunbar, "where he was both minister and schoolmaster," he adds that he "made that Rudiments, *Quum Literarum Consideratio*, whilk for that were called *Dunbar Rudiments*." Row, *Historie of the Kirk of Scotland*, p. 9, and see p. 422 (Wodrow Society.)

This is an exceedingly useful book of the kind. The difficulty was felt, then as now, of encumbering pupils of tender years with complex rules and lists of exceptions, and on the other hand of reducing grammar to a mere outline. The distinction was recognised between what we know as the *Rudiments* and the *Principles* of Grammar, a distinction which was maintained by Ruddiman who published first in Latin and English *The Rudiments of the Latin Tongue*, and then in Latin, *Grammaticae Latinae Institutiones*, or what is known, nowadays, as "A Complete Latin Grammar."

Simson's *Rudiments* explains succinctly with examples, the five declensions of nouns, the declension and comparison of adjectives, the pronouns, the conjugation of verbs, and the indeclinable parts of speech. This is followed by a short syntax, which, however, is perhaps too brief to be useful. All reference to the genders of nouns and the long lists of irregular nouns to be found in the full grammars are omitted. So much of this as was considered requisite, as well as a fuller exposition of the rules of syntax, was no doubt intended to be supplied by oral explanation by the teacher. The *Rudiments* likewise omitted any reference to Prosody; probably as being beyond the scope of an elementary work, certainly not on account of any neglect of the subject itself, as Latin verse writing was sedulously practised in Scotland during the whole of the sixteenth and the greater part of the eighteenth centuries.[1] We are sometimes accustomed to think that this was an accomplishment peculiar to England, but this is not so.

The rules of Syntax are necessarily much the same, as in other earlier and contemporary grammars, which in turn borrowed from still older sources. Ruddiman improved upon Simson's arrangement, making it more logical, but to a large extent the rules are the same and were made familiar during many years to most schoolboys in Scotland through the *Edinburgh Academy Rudiments* which were in turn an improvement upon Ruddiman.

James Kirkwood found great fault with the *Rudimenta Grammatices*. There was he said much useless matter in it, which was

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[1] The General Assembly in 1645 enacted "that for the remedy of the great decay of poesie, and of ability to make verse, and in respect of the common ignorance of prosody, no schoolmaster be admitted to teach a Grammar School n burghs or other considerable parishes, but such as after examination, shall be found skilful in the Latin tongue, not only for prose, but also for verse."—Act of Assembly, 1645, Sess. 14, Feb. 7. Peterkin, *Abridgment*, p. 311.

a mere burden to the memory, much that was out of place in simple *Rudiments*, and also many mistakes.[1]

Along with the *Rudimenta*, there are bound up :—

(*a*) David Williamson's *Vocabula.*
(*b*) *Rudimenta Pietatis.*
(*c*) *Dicta Sapientum.*
(*d*) Joannis Sulpitii *De Moribus & Civilitate Puerorum Carmen.*
(*e*) Dionysii Catonis *Disticha,*
à J. R. [*i.e.*, James Rae.]

These pieces are found in most editions of the *Rudimenta*, and Ruddiman adhering to the practice appended them to his *Rudiments of the Latin Tongue.*

They will be referred to later on along with Reading Books and Vocabularies.

[1] Kirkwood, *Grammatica Facilis*, p. 1, sqq.

Rules Governing the Competition for the Graham Medal.

1. The competition for the Graham Medal shall be under the authority and control of the Council of the Royal Philosophical Society of Glasgow, whose decision on all points connected therewith shall be final.

2. Each candidate shall forward to the Secretary of the Royal Philosophical Society of Glasgow, 207 Bath Street, Glasgow, on or before 14th March of the year in which the competition is held, a paper giving an account of an unpublished original research conducted by himself in any branch of chemical science.

3. The medal shall be awarded to the candidate whose research, in the opinion of the Council, or of the person or persons whom they may appoint to adjudicate in the matter, is of the highest merit, and most likely to aid in the advancement of chemical science.

4. The successful candidate shall read the paper, on account of which the medal is awarded, to the Royal Philosophical Society of Glasgow. The paper shall thereafter be published in the *Proceedings* of the Society, and its publication elsewhere shall not take place without the permission of the Council.

5. No award shall be made if, in the opinion of the Council, no candidate has contributed a paper of sufficient merit.

MINUTES OF SESSION.

1904-1905.

2nd November, 1904.

The First Ordinary Meeting, for Session 1904-1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 2nd November, 1904, at eight o'clock. The President, Professor Archibald Barr, D.Sc., occupied the chair.

1. The President intimated that no Minute would be read, as that for the previous Meeting was published in the last issue of the *Proceedings*, and had been read and approved at the close of the Meeting itself.

2. Mr Walter M. N. Reid was admitted to Membership of the Society.

3. The President made reference to the death of Dr J. B. Russell, a former president of the Society, and for many years Medical Officer for the City of Glasgow, and moved that a vote of condolence be passed, and a fitting expression of the sympathy of the Society be sent to the family of the late Dr Russell. The motion was unanimously agreed to.

It was also remitted to the Council to take what further steps were usual in such circumstances.

4. The President also announced that the new Library Catalogue was now ready, but, by regulation of the Council, would be issued only to Members who called for it at the Rooms.

5. Professor E. A. Schäfer, LL.D., F.R.S., Edinburgh University, delivered a lecture, with illustrations and demonstrations, on "Methods of Artificial Respiration."

A vote of thanks was accorded to Professor Schäfer on the motion of Dr James Finlayson, seconded by Professor Glaister, and supported by the President. Some points of the lecture were discussed by these and also by Mr Mavor and Dr Barr Pollock.

6. Mr Hugh Osborne and Dr Lewis M'Millan were appointed to audit the accounts of the Society.

7. The Hon. Secretary announced that the following gentlemen had been duly elected Members of the Society:—

1. Mr JOHN H. BALLANTYNE, 212 Bath Street.
2. The Right Reverend Bishop ARCHIBALD E. CAMPBELL, D.D., Bishop's House, Woodside Terrace, Glasgow.
3. Mr WARREN CROSBIE, B.L., Solicitor, 141 St Vincent Street.
4. Mr GEORGE FERGUSON, Merchant, 130 Bishop Street, Port Dundas.
5. Mr JOHN MACKINNON, 22 Carmichael Street, Govan.
6. Dr JOHN M'VAIL, D.P.H. (Camb.), County Medical Officer, Stirlingshire and Dumbartonshire, 20 Eton Place, Hillhead, Glasgow.
7. Mr JAMES NESS, M.A., LL.B., Writer, 216 West George Street.
8. Mr JAMES A. REID, Dean of Faculty of Procurators, 172 St Vincent Street.

REPORT OF COUNCIL FOR SESSION, 1903-1904.

I. *Centenary Lectures.*—In his Presidential address at the opening of the Centenary Session, 1902-1903, Professor Archibald Barr remarked that it would be extremely interesting to trace the growth of Science during the life-time of the Society, and suggested the organising of a course of lectures dealing with the advancement of pure and applied Science during the Nineteenth Century. The Council adopted the suggestion and succeeded in arranging a course of five special lectures, which were delivered at regular intervals during the Session by Professor Andrew Gray, Professor G. G. Henderson, Mr Geo. T. Beilby, Professor Robert Muir, and Dr Robert Caird. These "Centenary" Lectures proved eminently successful, and the audiences assembled to hear them were unusually large.

II. *Meetings.*—The first Meeting of the Society for Session, 1903-1904 was held in the Natural Philosophy Class Room, Glasgow University, where Professor Andrew Gray opened the Session with the first of the Centenary Lectures, the subject being "The Progress of Electricity in the Nineteenth Century and the Electro-magnetic Theory of Light." Fifteen meetings were held during the Session, twelve ordinary, one special, and two extraordinary meetings. At the extraordinary meetings revised Articles of Association were passed. The special meeting was held in the Physiology Class Room, Glasgow University, on the invitation of Professor M'Kendrick, who gave a lecture on "Voice Tones." At the ordinary meetings sixteen communications were made to the Society.

III. *The Sections.*—The activity of the Sections is well shown by the fact that, excepting the Centenary Lectures and one short paper, all the communications to meetings of the Society were from one or other of the Sections. In

addition many sectional meetings were held for the purpose of reading and discussing papers. As usual the Architectural Section published a complete syllabus of sectional papers early in the Session.

IV.—*Articles of Association.*—The Council was occupied during this and the previous Session in revising the Articles of Association of the Society. The revised Articles were passed at an extraordinary meeting of the Society on 6th April and confirmed at a second extraordinary meeting held on 27th April. The altered Constitution appears as an appendix to Vol. XXXV. of the *Proceedings.*

V. *Proceedings.*—The thirty-fifth volume of the *Proceedings* was issued to Members about the end of October. It contains seventeen papers including the five Centenary Lectures.

VI. *Library.*—Annexed is the Report of the Hon. Librarian, which shows the additions made to the Library during the Session. The new catalogue of books, prepared by Mr Robertson, is also reported upon.

VII. *Graham Medal.*—There were no entries in competition for the Graham Medal.

VIII. *Membership.*—During the Session, 33 Members were elected, and 1 was reinstated from the Suspense List. Forty-four have resigned, 14 have died, and 1 has been placed on the Suspense List. The following are the deaths, viz.—Messrs. Thomas Balmain, Gilbert Beith, George S. Buchanan, D. S. Cargill, Thomas W. Cuthbertson, Wm Dennison, A. D. Dixon, J. G. Macarthur, John Maxton, James B. Mirrlees, H. L. Seligmann, Robert Sorley, W. Stewart, and J. M. Taylor, two of whom were Life Members. Besides these there occurred the deaths of two Honorary Members, Herbert Spencer, and Dr Jas B. Russell. Of the New Members admitted during the Session, 6 qualified themselves as Life Members, and 5 Old Members likewise qualified. There are now 283 Members of that class out of 332 who have so enrolled themselves. The roll now includes 16 Honorary Members, 19 Corresponding Members, and 950 Ordinary Members (Annual and Life), or a total of 985.

IX. *Finance.*—The Treasurer's statement for 1903-1904 opens with an investment in railway stock of £47 9s. (the remainder at cost, of a larger investment partly sold), and £450 on deposit, less a balance due him of £10 16s. 1d., making £486 12s. 11d. The accounts close with the same investment, and £850 deposited with the Corporation of Glasgow, less £109 10s. 5d., due to the Treasurer, making £787 18s. 7d. It is believed that, as usual at the close of the financial year, the Society has practically no outstanding liability.

Separate statements are given by the Treasurer, as formerly, showing the position of the two funds which the Society holds in trust, viz.—"The Graham Medal and Lecture Fund" and "The Glasgow Science Lecture Fund," the balances of revenue being £81 19s. 2d. and £52 15s. 7d. respectively.

FREELAND FERGUS, *Hon. Secretary.*
PETER BENNETT, *Acting Secretary.*

REPORT OF THE LIBRARY COMMITTEE.

The Library Committee has to report that during last year 1,301 books were issued by the Librarian to 842 members. Consultations of books were numerous, and much use was made of the Reading Room.

Exclusive of periodicals 100 volumes and 12 parts of works were added to the Library by purchase, and 55 volumes, 11 parts of works and 23 pamphlets were presented.

The periodicals received at the Library numbered 109 of which 69 were bought and 40 were sent in exchange.

The *Proceedings* of the Society were forwarded to 190 Societies and Public Bodies, and 183 volumes and 161 parts of works were received in exchange. These included 44 volumes of Abridgments of Specifications of Patents.

Altogether during the year there were added to the Library 443 volumes, 187 parts of works and 23 pamphlets. The number of complete volumes exclusive of pamphlets now reaches an estimated total of 15,395.

Since last report 247 volumes have been bound.

The South African Association for the Advancement of Science, the Transvaal Department of Agriculture, the Electrical Publishing Company, London, the Engineering Review, the College of Science and Engineering of Kyōto Imperial University, New York State Library, and the Glasgow University Library, have been added to the list of Exchanges.

The printing of the new catalogue of the books in the Library was completed in June. Members who have not already received copies can procure them from the Librarian.

JOHN ROBERTSON, HON. LIBRARIAN,
Convener.

16th November, 1904.

The Annual General Meeting, for Session 1904-1905, of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 16th November, at eight o'clock. The President, Professor Archibald Barr, occupied the chair.

1. The Minute of the previous Meeting, of date 2nd November, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. The Annual Report by the Council (printed in the Second Billet) was held as read, and was adopted on the motion of the President, seconded by Professor Glaister.

4. The Hon. Treasurer's Abstracts of Accounts for the past year, signed by the Auditors, Mr Hugh Osborne and Dr Lewis M'Millan, were submitted, and adopted on the motion of Mr John Mann, Jun., seconded by Mr J. M'Kellar.

Mr M'Kellar drew attention to the fact that no mention was made in the Honorary Treasurer's Abstracts of the joint fund in the hands of the Corporation. In the absence of the Honorary Treasurer no explanation could be given.

A vote of thanks was passed to the Auditors on the motion of Dr Fergus.

5. The Report of the Library Committee was submitted, and was adopted on the motion of the Honorary Librarian, seconded by Dr Fergus, and a vote of thanks passed to donors of books.

6. The President moved a vote thanks to the Honorary Librarian, and submitted the following recommendation of the Council, viz., "That Mr John Robertson be presented with an honorarium of fifty guineas for special services rendered to the Society in connection with the preparation of the new Library Catalogue." Dr Neilson seconded, and the recommendation was adopted unanimously.

7. On the motion of the Chairman, seconded by Prof. Glaister Dr David Murray was elected President of the Society for the ensuing term of office.

Dr Neilson moved a vote of thanks to Professor Barr for his services to the Society during his occupancy of the Presidential Chair. The motion was cordially responded to.

8. Professor Andrew Gray was elected a Vice-President in room of Professor Maclean, on the motion of Dr Neilson.

9. On the motion of Mr Ewing, Mr John Robertson, Mr John Mann, and Dr Freeland Fergus were re-elected Honorary Librarian, Honorary Treasurer, and Honorary Secretary, respectively, and received the thanks of the Meeting for their services during the past year.

Dr. ABSTRACT OF HONORARY TREASURER'S

AND COMPARISON WITH

			1903-1904.	1902-1903.
			£ s. d.	£ s. d.
To BALANCES from last year—				
Investment, Caledonian Railway £110, 3 per cent. Preferred, Converted,	£47 9 0			
Deposit— Corporation of Glasgow,	450 0 0			
		£497 9 0		
Less, due Treasurer,		10 16 1		
			486 12 11	*409 16 9*
,, SUBSCRIPTIONS to 31st October, 1904—				
33 Entry-moneys of 1903-1904, at 21s.,	£34 13 0			
Annual Dues at 21s —				
Arrears,	3 3 0			
For 1903-1904, 656 Ordinary Members,	688 16 0			
Do., 27 New Members,	28 7 0			
		754 19 0		
Life Subscriptions at £10 10s.—				
5 Old Members,	£52 10 0			
6 New Members,	63 0 0			
		115 10 0		
			870 9 0	*1042 13 0*
,, SUBSCRIPTIONS OF ASSOCIATES OF SECTIONS—				
ARCHITECTURAL, 85 Associates, at 5s.,			21 5 0	*19 15 0*
MATHEMATICAL AND PHYSICAL, 4 Associates, at 5s.,			1 0 0	*1 5 0*
ECONOMIC SCIENCE, 30 Associates, at 5s.,			7 10 0	*8 5 0*
GEOGRAPHICAL AND ETHNOLOGICAL, 2 Associates, at 5s.,			0 10 0	*1 5 0*
HISTORICAL AND PHILOLOGICAL, 9 Associates, at 5s.,			2 5 0	*2 15 0*
,, DIVIDENDS, ETC.—				
Dividends on Caledonian Railway Stock,		£3 2 11		
Interest on Deposit with Corporation,		9 13 6		
Bank Interest,		1 3 2		
Proceedings, etc., sold,		1 9 4		
			15 8 11	*17 13 0*
			£1405 0 10	*1503 7 9*

Memo.—The Society's Investments are—

(1) Bath Street Joint Buildings, as in last Account,	£3,933 7 4½
(2) Caledonian Railway Stock, as above (present value, £83 12s. od.),	47 9 0
(3) Deposit with Corporation of Glasgow,	850 0 0
	£4,830 16 4½

ACCOUNT—SESSION 1903-1904. *Cr.*

SESSION 1902-1903.

				1903-1904.			*1902-1903.*		
				£	S.	D.	£	S.	D.
By MANAGEMENT EXPENSES—									
Remuneration to Acting Secretary,	£100	0	0						
Allowance for Treasurer's Clerks,	15	0	0						
Commission to Collectors,	6	7	5						
Telephone Rent, and extra insertion in Directory, 5s.	5	10	0						
Stationery,	2	18	0						
Fire Insurance on Library,	6	10	0						
Reporting	1	10	0						
Postages, etc. Per Secretaries, £9 1s. 2d.; per Treasurer, £5 9s. 6d.,	14	10	8	152	6	1	*158*	*3*	*1½*
,, EXPENSES OF ROOMS, one half of £391 11s. 6d.; less half of £101 18s. 6d. received for Lettings,				144	16	6	*216*	*10*	*8*
,, LIBRARY—									
New Books and Periodicals, British and Foreign,	£120	6	5						
Bookbinding,	25	18	10	146	5	3	*207*	*19*	*6*
,, PRINTING, ETC.—									
Printing *Proceedings*, Circulars, etc.,	£123	14	10½						
Postage and delivery of Circulars,	33	15	8½	157	10	7	*260*	*10*	*6*
,, CENTENARY CELEBRATIONS,				0	0	0	*153*	*11*	*11½*
,, SUBSCRIPTIONS TO SOCIETIES—									
Ray Society, 1904,	£1	1	0						
Palæontographical Society, 1904,	1	1	0						
Sanitary Institute, 1904,	1	1	0	3	3	0	*3*	*3*	*0*
,, EXPENSES OF SECTIONS PER SECRETARIES—									
Architectural,				11	10	1	*11*	*18*	*8*
Mathematical and Physical,				0	2	6	*0*	*3*	*11*
Economic Science,				0	11	0	*2*	*18*	*11*
Geographical and Ethnological,				0	0	0	*0*	*5*	*0*
Historical and Philological,				0	9	5	*0*	*16*	*1*
Sanitary and Social Economy,				0	7	10	*0*	*13*	*6*
,, INVESTMENTS—									
Caledonian Railway £110, 3 per cent Preferred, Converted (Balance),	£47	9	0						
Corporation of Glasgow, on Deposit,	850	0	0						
	897	9	0						
,, Less Balance due to Treasurer,	109	10	5	787	18	7	*486*	*12*	*11*
				£1405	0	10	*1503*	*7*	*9*

GLASGOW, 9th November, 1904.—We, the Auditors appointed by the Society to examine the Treasurer's Accounts for the year 1903-1904, have examined the same, of which the above is an Abstract, and have found them correct, the Balance due to Treasurer being One Hundred and Nine Pounds, Ten Shillings and Five Pence Sterling.

(Signed) HUGH OSBORNE.

JNO. MANN, C.A., *Honorary Treasurer*. (,,) A. LEWIS M'MILLAN.

GRAHAM MEDAL AND LECTURE FUND.

ABSTRACT OF TREASURER'S ACCOUNT, Session 1903-1904.

Dr.

Capital at 1st November, 1903—		
Glasgow and South-Western Railway Co. 4 Per Cent. Preference Stock in name of the Philosophical Society, in Trust,	£250 0 0	
Value of Die at H.M. Mint,	18 18 0	
		£268 18 0
Cash in Bank,		71 0 1
Revenue—		
Dividend, March, 1904, less Tax	£4 15 5	
,, Sept., ,, ,,	4 15 2	
Interest from Bank,	1 8 6	
		10 19 1
		£350 17 2

Cr.

Capital at 31st October, 1904—		
Investment, *per contra*, (present value, £289 7s. 6d.),	£250 0 0	
Die,	18 18 0	
		£268 18 0
Balance, being Revenue—		
In Bank, on Deposit Receipts,		81 19 2
		£350 17 2

Glasgow, 9th November, 1904.—Examined and found correct.

(Signed HUGH OSBORNE.
A. LEWIS M'MILLAN.

JNO. MANN, C.A., *Honorary Treasurer.*

THE SCIENCE LECTURES ASSOCIATION FUND.

ABSTRACT OF TREASURER'S ACCOUNT—Session 1903-1904.

Dr.

Capital at 1st November, 1903—		
£200 Caledonian Railway Company 4 Per Cent. Preference Stock, No. 1, in name of the Philosophical Society, in Trust, cost,	£244 4 8	
On Deposit Receipt,	8 5 4	
		£252 10 0
Cash in Bank (Revenue),		44 2 7
Revenue—		
Dividend, April 1904, less Tax,	£3 16 4	
,, Oct., ,, ,,	3 16 1	
Interest from Bank,	1 0 7	
		8 13 0
		£305 5 7

Cr.

Capital at 31st October, 1904—		
Investment, *per conta*, (present value, £234),	£244 4 8	
In Bank, on Deposit Receipt,	8 5 4	
		£252 10 0
Balance, being Revenue—		
In Bank, on Deposit Receipt,		52 15 7
		£305 5 7

Glasgow, 9th November, 1904.—Examined and found correct.

(Signed) HUGH OSBORNE.
A. LEWIS M'MILLAN.

JNO. MANN, C.A., *Honorary Treasurer.*

10. The Chairman intimated that as some of the gentlemen whose names appeared on the agenda as nominees for the ordinary vacancies in the Council could not see their way to accept office, the Council recommended and he moved that Mr Hugh Reid, Mr F. T. Barrett, Mr James J. MacLehose and Mr J. Craig Annan, be elected Members of Council. Dr Fergus seconded, and the gentlemen named were elected by the Meeting.

11. Office-bearers of the different Sections (see pp. 320, 321) were proposed as below and elected :—

(*a*) For the Georgraphical and Ethnological Section—Dr Mackenzie Anderson proposed those on list, p. 321.

(*b*) For the Sanitary and Social Economy Section—Mr William Buchanan proposed those on list, p. 320.

(*c*) For the Mathematical and Physical Section—Professor Andrew Gray proposed those on list, p. 321.

(*d*) For the Economic Science Section—Mr John Mann, Jun., proposed those on list, p. 321.

(*c*) For the Historical and Philological Section—Mr John Clark proposed those on list, p. 321.

12. A vote of thanks to the retiring Office-bearers was passed on the motion of the Chairman.

13. Dr R. M. Buchanan, City Bacteriologist, read a paper on "Stone Decay," with lantern illustrations. The paper was a communication from the Sanitary and Social Economy Section.

A discussion followed in which part was taken by Mr Falconer, Mr Beilby, Mr Robertson, Professor Glaister, Dr Fergus, Dr Knight, Professor A. Gray, Professor Barr, and Dr Buchanan.

The thanks of the Meeting were accorded to Dr Buchanan on the motion of the Chairman.

14. The Honorary Secretary announced that the following gentlemen had been duly elected Members of the Society :—

1. Mr Waldemar Arend, 1 Queensborough Gardens.
2. Professor J. Graham Kerr, M.A., Regius Professor of Zoology, Glasgow University, 15 Clarence Drive, Hyndland.
3. Mr John Bowers, Depute Town Clerk, Glasgow, City Chambers.

30th November, 1904.

The Third Ordinary Meeting, for Session 1904-1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 30th November, at eight o'clock. The President, Dr David Murray, occupied the chair.

Dr Murray thanked the Members for the honour they had done him in electing him President.

1. The Minute of the previous Meeting, of date 16th November, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. The Hon. Secretary read the letter of condolence he had sent to Mr David Russell, son of the late Dr J. B. Russell, and the reply thereto.

4. On the motion of the Chairman, seconded by Mr Robert Blyth, the resolution passed at last meeting, viz., "That Mr John Robertson be presented with an honorarium of fifty guineas for special services rendered to the Society in connection with the preparation of the new Library Catalogue," was confirmed.

5. Mr William Milne, M.A., B.Sc., Department of Public Education, Cape Colony, read a paper entitled "On the Function of the Water Vascular System in Rotifera," with Notes on some South African Floscularia. Some points of the paper were afterwards discussed by Professor J. Graham Kerr, and Mr Milne.

A vote of thanks was passed to Mr Milne on the motion of the Chairman.

6. Professor Robert Wallace, F.R.S.E., F.L.S., F.C.S., Edinburgh University, delivered a lecture, with numerous lantern illustrations, on "Some Interesting Features of the Argentine Republic," being a communication from the Geographical and Ethnological Section.

Professor Wallace received the thanks of the Meeting on the motion of Mr Robert Blyth, seconded by the Chairman.

7. The Honorary Secretary announced that the following gentlemen had been duly elected to Membership of the Society :—

HONORARY.

Sir WILLIAM RAMSAY, K.C.B., LL.D., D.Sc., Ph.D., F.R.S., Professor of Chemistry, University College, London, 19 Chester Terrace, Regent's Park, London, N.W.

ORDINARY.

1. Mr FRANK BEAUMONT, B.A. (Lond.), English Master, High School of Glasgow, 19 Grantly Gardens, Shawlands.
2. Professor J. W. GREGORY, D.Sc., F.R.S., Glasgow University.
3. Dr D. O. MACGREGOR, Victoria Infirmary.
4. Mr JAMES MUIR, D.Sc., M.A., 189 Renfrew Street.
5. Mr EDWAND J. THOMSON, Western Club, Glasgow.

14th December, 1904.

The Fourth Ordinary Meeting, for Session 1904-1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 14th December, 1904, at eight o'clock. In the absence of the President and Vice-Presidents Dr Freeland Fergus occupied the chair by request of the Meeting.

1. The Minute of the previous Meeting, of date 30th November, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Mr James Colville, M.A., D.Sc., read a paper entitled "Francis Bacon's Theory of Education."

A discussion followed in which part was taken by Mr John Macdonald, Mr Robert Ness, Mr William Ness, Dr Fergus and Dr Colville.

A vote of thanks was passed to Dr Colville on the motion of the Chairman, who remarked that the Meeting was under special obligation to Dr Colville for coming forward at very short notice to take the place of Mr Gulston who had been prevented by indisposition from fulfilling his engagement.

4. The Chairman announced that the following gentlemen had been duly elected to Membership of the Society :—

1. Mr THOMAS GRAY, D.Sc , Ph.D., Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, 60 John Street.
2. Mr FREDERICK SODDY, M.A., Chemistry Department, Glasgow University.

11th January, 1905.

The Fifth Ordinary Meeting, for Session 1904-1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 11th January, 1905, at eight o'clock. The President, Dr David Murray, occupied the chair.

1. The Minute of the previous Meeting, of date 14th December, 1904, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Professor Magnus Maclean, M.A., D.Sc., F.R.S.E., delivered a lecture, illustrated by lantern slides and experiments, on "Developments of Electric Signalling during the Nineteenth Century."

The lecture was one of the Centenary Series on the advancement of Science in the Nineteenth Century. A vote of thanks was accorded to Professor Maclean on the motion of Mr H. A. Mavor, seconded by Professor Archibald Barr, and supported by the Chairman.

4. The Hon. Secretary announced that the Rev. Edward Bruce Kirk, E U. Manse, Barrhead, had been duly elected to Membership of the Society.

5. The following letter from Sir William Ramsay was read by the Hon. Secretary :—

UNIVERSITY COLLEGE, LONDON,
GOWER STREET, W.C., *2nd December, 1904.*

DEAR DR FERGUS,

I am much obliged for your communication that the Royal Philosophical Society has done me the honour of making me one of its Honorary Members. It is long since I have attended a meeting,

but I look back with much pleasure on evenings spent in the old Art Gallery in Sauchiehall Street. My father was a member: and perhaps it may interest the Society to know that the Glasgow Chemical Society, founded in 1798, had as its chairman my grandfather, and that when the Philosophical Society was started (I think in 1802), the Chemical Society merged itself in the Philosophical.

Please convey my warm thanks to the Society for the honour they have done me.

Yours sincerely,

(Signed) W. RAMSAY.

25th January, 1905.

The Sixth Ordinary Meeting, for Session 1904.1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 25th January, 1905, at eight o'clock. The President, Dr David Murray, occupied the chair.

1. The Minute of the previous Meeting, of date 11th January, 1905, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The Rev. Edward Bruce Kirk, E.U. Manse, Barrhead, was admitted in absence.

3. The following communications from the Mathematical and Physical Section were read:—

(i) "Note on Radio-Activity," illustrated by diagrams and lantern slides, by Mr H. Stanley Allen, M.A., B.Sc. Professor Gray and Mr Frederick Soddy took part in a discussion which followed.

A vote thanks was passed to Mr Allen on the motion of the Chairman.

(ii) "The Effect of Tensile Overstrain on the Magnetic Properties of Iron," illustrated by lantern slides, by Mr James Muir, D.Sc., M.A., and Mr Archibald Lang, M.A., B.Sc. Appreciative remarks were made on the paper by Professor Gray, and a vote of thanks to the authors was passed on the motion of the Chairman.

(iii) "Some recent Research Instruments in Physics," by Professor James Blyth, M.A., LL.D., illustrated by experiments. Professor Gray discussed some points connected with the subject matter of the paper, and a vote of thanks to Professor Blyth was passed on the motion of the Chairman.

4. The Hon. Secretary announced that the following gentlemen had been duly elected to Membership of the Society :—

1. Mr ARTHUR L. JONES, 1027 Sauchiehall Street.
2. Mr GEORGE M'CALMAN, 1 India Street, West.

8th February, 1905.

The Seventh Ordinary Meeting, for Session 1904 1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 8th February, 1905, at eight o'clock. The President, Dr David Murray, occupied the chair.

1. The Minute of the previous Meeting, of date 25th January, 1905, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Professor L. Becker, Ph.D., delivered the Centenary Lecture on "The Progress of Astronomy in the Nineteenth Century." The lecture was illustrated by numerous lantern slides.

On the motion of Professor Gray a vote of thanks was accorded to Professor Becker.

22nd February, 1905.

The Eighth Ordinary Meeting, for Session 1904-1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 22nd February, 1905, at eight o'clock. The President, Dr David Murray, occupied the chair.

1. The Minute of the previous Meeting, of date 8th February, 1905, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The following letter from the Hon. Librarian, Mr John Robertson, was read :—

207 BATH STREET,
GLASGOW, *18th February, 1905.*

DEAR DR FERGUS,

Kindly convey to the Council of the Society my hearty thanks for their handsome recognition of my services in connection with the preparation of the new catalogue of the books in the Library.

Although the work was laborious it was a labour of love, and I should have preferred a simple expression of thanks ; but the Council, in their goodness of heart, having agreed to the proposal, I accept the cheque as a tangible token of their appreciation of my services, and of their satisfaction with the resulting volume.

I am,

Faithfully yours,

JOHN ROBERTSON.

3. A letter from Dr A. K. Chalmers, Medical Officer of the City, was read, intimating that a microscope, and a volume on the "Microscope in Medicine," purchased by the late Dr J. B. Russell with the Lord Rector's Prize-money in 1861, were left by him to the Society, and forwarded by his son, Mr David Russell. The microscope and book were exhibited at the Meeting.

4. The Standing Orders having been suspended on the motion of the Chairman, the Hon. Secretary, Dr Freeland Fergus, drew the attention of the Meeting to the death of Professor R. S. Thomson, M.D., D.Sc., and it was unanimously agreed to record the deep regret of the Society at the death of so distinguished and brilliant a member of the Medical Profession, and of so useful a member of the Society's Council. The Meeting directed the Hon. Secretary to convey to Mrs Thomson an expression of their most sincere and respectful sympathy with her in her sorrow.

5. Dr John Brownlee, M.A., Physician Superintendent, Belvidere, read a Biographical Sketch of the late Dr James B. Russell.

A vote of thanks was accorded to Dr Brownlee on the motion of the Chairman.

6. The President here intimated that negotiations were in progress, on the initiative of the Council of the Engineers and Shipbuilders, for the sale of their interest in the Buildings to the Society. As such a transaction could not take place without the sanction of the Society the Council would submit the matter in due form when the proper stage was reached.

7. Mr Frederick Soddy, M.A., delivered a lecture on "The Atom," with numerous illustrations and experiments. The lecture was a communication from the Mathematical and Physical Section. A discussion followed in which part was taken by Dr Brownlee, Prof. Blyth, and Dr. Muirhead. Mr. Soddy replied, and was accorded a vote of thanks on the motion of the Chairman.

8th March, 1905.

The Ninth Ordinary Meeting, for Session 1904 1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 8th March, 1905, at eight o'clock. The President, Dr David Murray, occupied the chair.

1. The Minute of the previous Meeting, of date 22nd February, 1905, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. Professor J. Graham Kerr, M.A., delivered the Centenary Lecture on "The Evolution of Zoological Science during the Nineteenth Century." The Lecture was illustrated by coloured drawings.

A vote of thanks was accorded to Professor Kerr on the motion of Dr J. W. Allan, seconded by the President.

22nd March, 1905.

The Tenth Ordinary Meeting, for Session 1904-1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 22nd March, 1905, at eight o'clock. In the absence of the President Mr William Ewing, Vice-President, occupied the chair.

1. The Minute of the previous Meeting, of date 8th March, 1905, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The Hon. Secretary read the nominations of the Council for the offices to be filled at the election on 19th April, and drew attention to the new regulation under which additional nominations might be made by Members of the Society. The nominations of the Council were—Vice-President, Mr H. A. Mavor; Members of Council, Professor L. Becker, Mr George Barclay, Dr William Snodgrass, Mr J. J. Spencer, Professor Dudley J. Medley, and Mr William Fraser.

3. Mr H. Stanley Allen, M.A., B.Sc., delivered a lecture, illustrated by numerous experiments with liquid air, on "Experimental Work at Low Temperatures." Appreciative remarks were made and questions asked by Mr Falconer, Mr Soddy, Mr Sam Mavor, Professor Blyth, and Mr Gibson. A vote of thanks was accorded to the lecturer on the motion of the Chairman.

Mr Allen in replying expressed indebtness to Lord Blythswood for facilities afforded, without which the experiments shown could not have been made.

4. The Hon. Secretary announced that the following gentlemen had been elected to Membership of the Society:—

1. Mr EDWARD J. BLES, B.A. (Cantab.), B.Sc. (Lond. and Vict.), Natural History Department, University of Glasgow.
2. Professor L. A. L. KING, 8 Ardgowan Terrace, Sandyford, Glasgow.
3. Mr JAMES BURNS, 2 Caird Drive, Partick.

5th April, 1905.

The Eleventh Ordinary Meeting, for Session 1904-1905 of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 5th April, 1905, at eight o'clock. The President, Dr David Murray, occupied the chair.

1. The Minute of the previous Meeting, of date 22nd March, 1905, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. The New Members elected at the previous Meeting were duly admitted.

3. Dr A. K. Chalmers, Medical Officer for the City of Glasgow, delivered the Centenary Lecture on the "Development of Sanitation during the Nineteenth Century."

A discussion on the subject of the lecture was taken part in by Dr John Brownlee, Dr Eben. Duncan, Dr M'Vail, Mr Menzies, and Mr Motion.

A vote of thanks was accorded to Dr Chalmers on the motion of Professor Archibald Barr, seconded by Mr James R. Motion.

19th April, 1905.

The Twelfth Ordinary Meeting, for Session 1904-1905, of the Royal Philosophical Society of Glasgow, was held within the Rooms, 207 Bath Street, on the evening of Wednesday, 19th April, 1905, at eight o'clock. The President, Dr David Murray, occupied the chair.

1. The Minute of the previous Meeting, of date 5th April, 1905, having been printed in the Billet calling the Meeting, was held as read, was approved, and was thereupon signed by the Chairman.

2. In accordance with the Articles of Association, the election of office-bearers to fill the vacancies in the Council was then proceeded with.

The President on behalf of the Council proposed the following who were thereupon elected:—

(i) Vice-President, Mr Henry A. Mavor.

(ii) Hon. Librarian, Hon. Treasurer, and Hon. Secretary, Mr John Robertson, Mr John Mann, and Dr Freeland Fergus, respectively.

(iii) Four Members of Council for a period of three years:—Professor L. Becker, Mr George Barclay, Mr J. J. Spencer, and Mr William Fraser.

(iv) Two Members of Council for a period of one year:—Professor Dudley J. Medley, and Dr William Snodgrass.

3. The President intimated that the Council, by request, had recently resuscitated the Biological Section, which for some years had been in abeyance, and Prof. Bower had been nominated President of that Section. The term of office of the Presidents of the Economic Science Section and of the Geographical and Ethnological Section had expired, and for these offices respectively Mr Thomas Jones and Mr Sam Mavor had been nominated. He proposed these gentlemen on behalf of the Sections named. The proposal was adopted.

4. On the motion of the President Mr N. B. Gunn and Mr C. D. Gardner were appointed to audit the accounts of the Society, and failing either, Mr James Borthwick, who had previously served.

5. Mr Charles E. Fawsitt, D.Sc., then read a paper entitled "The Education of the Examiner," being a communication from the Mathematical and Physical Section. The paper was illustrated by lantern slides. A discussion followed in which part was taken by Prof. Gray, Dr Dyer, Dr Muirhead, Mr Donald, Prof. Blyth, Dr Fergus, the President and Dr Fawsitt.

A vote of thanks was accorded to Dr Fawsitt on the motion of the Chairman.

6. The foregoing Minute was read by the Secretary and approved, and the Chairman was authorised by the Meeting to sign it when engrossed in the Minute-book.

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OF THE

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SESSION 1904-1905.

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Fahie, J.J. Galileo: his Life and Work. 1903.

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British Graptolites, Part 4. By Gertrude L. Elles, and Ethel M. R. Wood. 1904.

Fishes of the Old Red Sandstone of Britain, Part 2, No 2. By R. H. Traquair. 1904.

Palaeontographical Soctety's Publications—

Lower Palaeozoic Tribolites of the Girvan District, Ayrshire, Part 2. By F.R.C. Reed. 1904.

Inferior Oolite Ammonites of the British Isles, Part 12. By S.S. Buckman. 1904.

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Schuster, Arthur. Introduction to the theory of Optics. 1904.

Spencer, Baldwin, and Gillen, F. J. Northern Tribes of Central Australia. 1904.

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Waddell, L. A. Lhasa and its Mysteries with a Record of the Expedition of 1903-4. 1905.

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THE ROYAL PHILOSOPHICAL SOCIETY EXCHANGES WITH THE FOLLOWING SOCIETIES, ETC. :—

AFRICA.

Cape Town—

Cape of Good Hope Observatory. The Astronomer Royal.

South African Philosophical Society.

Johannesburg—

South African Association for the Advancement of Science.

Pretoria—

Transvaal Department of Agriculture.

AUSTRALIA.

Brisbane—

Royal Geographical Society of Australasia.

Melbourne—

Royal Observatory Library.

Royal Society of Victoria, Victoria Street.

Sydney—

Geological Survey, Department of Mines and Agriculture.

Royal Society of New South Wales, 5 Elizabeth Street, North.

Technological Museum.

Royal Anthropological Society of Australasia.

Australian Association for the Advancement of Science. The University.

Australian Museum.

University Library.

BELGIUM.

Brussels—
Académie Royale des Sciences.
Observatoire Royale.
Société Royale Malacologique de Belgique. 14 Rue des Sols.

Liège—
Société Royal des Sciences.

BRAZIL.

Rio de Janeiro—
Museu Nacional do Rio de Janeiro.

CANADA.

Halifax—
Nova Scotian Institute of Science.

Hamilton (Ont.)—
Hamilton Association.

London (Ont.)—
Entomological Society of Ontario.

Montreal—
Canadian Society of Civil Engineers, 112 Mansfield Street.

Ottawa—
Geological Survey of Canada, Sussex Street.
Royal Society of Canada.

Quebec—
Literary and Historical Society of Quebec.

Regina—
Department of Agriculture, North-West Territories.

Toronto—
Canadian Institute, 58 Richmond Street, East.

Winnipeg—
Manitoba Historical and Scientific Society.

CHINA.

Hong Kong—
Hong Kong Observatory.

ENGLAND AND WALES.

Barnsley—
Midland Institute of Mining, Civil, and Mechanical Engineers, Elder Street.

Bath—
Bath Natural History and Antiquarian Field Club. Royal Literary Institution.

Birmingham—
Philosophical Society, Medical Institute, Edmund Street.

ENGLAND AND WALES—*continued.*

Bristol—

Bristol Naturalists' Society. Dr C. K. Rudge, Ashgrove House, 145 White Ladies' Road, Clifton.

Cambridge—

Philosophical Society, New Museum.

University Library. The Curator.

Cardiff—

Cardiff Naturalists' Society, Dr Griffith, 50 Newport Road.

South Wales Institute of Engineers, Park Place.

Falmouth—

Royal Cornwall Polytechnic Society.

Greenwich—

Royal Observatory. The Astronomer Royal.

Leicester—

Leicester Literary and Philosophical Society.

Liverpool—

Geological Society, Royal Institution, Colquitt Street.

Literary and Philosophical Society. Tate Librarian, University College.

Liverpool Engineering Society, Royal Institution, Colquitt Street.

London—

Anthropological Institute, 3 Hanover Square.

British Association for the Advancement of Science, Burlington House.

British Museum. The Superintendent, Copyright Office.

British Museum. Natural History Department, Cornwall Road.

Chemical Society, Burlington House.

Electrical Publishing Co., Ltd., 4 Southampton Row, Holborn, W.C.

Engineering. The Publisher, 35 Bedford Street, Strand.

Engineering Review Co., 104 High Holborn. W.C.

Institution of Civil Engineers, Great George Street, Westminster, S.W.

Institution of Mechanical Engineers, Storey's Gate, St. James' Park, Westminster.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S.W.

Patent Office Library, 25 Southampton Buildings, Chancery Lane.

Pharmaceutical Society, 17 Bloomsbury Square.

Royal Geographical Society, 1 Saville Row.

Royal Institute of British Architects, 9 Conduit Street, Hanover Square.

Royal Institution of Great Britain and Ireland, Albemarle Street, Piccadilly, W.

Royal Meteorological Society, 22 Great George Street, Westminster.

Royal Photographic Society, 66 Russell Square, W.

Royal Society, Burlington House.

Royal Statistical Society, 9 Adelphi Terrace, Strand.

Society of Arts, John Street, Adelphi.

Society of Biblical Archæology, 37 Great Russell Street, Bloomsbury.

Society of Chemical Industry, Palace Chambers, 9 Bridge Street, Westminster.

Technics. The Publishers, 3-12 Southampton Street, Strand.

ENGLAND AND WALES—*continued.*

Manchester—

Geographical Society, 16 St Mary's Parsonage.

Literary and Philosophical Society of Manchester, 36 George Street.

Middlesborough—

Cleveland Institution of Engineers.

Newcastle-upon-Tyne—

North-East Coast Institution of Engineers and Shipbuilders, 4 St Nicholas Buildings.

North of England Institute of Mining and Mechanical Engineers, Neville Hall.

Oxford—

Bodleian Library.

Stratford (Essex)—

Essex Field Club. Passmore-Edwards Museum, Romford Road.

Truro—

Royal Institution of Cornwall.

Watford—

Hertfordshire Natural History Society and Field Club (Endowed Schools).

Welshpool—

Powys-Land Club. The Secretaries, Museum and Library, Salop Road.

FRANCE.

Bordeaux—

Société des Sciences Physiques et Naturelles de Bordeaux.

Marseilles—

Faculté des Sciences de Marseille.

Paris—

École Polytechnique. The Director.

Observatoire Météorologique Central de Montsouris.

Rennes—

Library of the University.

GERMANY.

Berlin—

Deutsche Chemische Gesellschaft.

Deutsche Kolonial Verein.

Königliche Preussische Akademie der Wissenchaften.

Bremen—

Geographische Gesellschaft.

Giessen (Hesse)—

Oberhessische Gesellschaft für Natur-und-Heilkunde.

Griefswald (Prussia)—

Geographische Gesellschaft.

Halle (Prussia)—

Vereins für Erdkunde zu Halle.

Kaiserliche Leopoldino—Carolinische Deutsche Akademie der Naturforscher.

INDIA.

Calcutta—

Geological Survey of India.

IRELAND.

Belfast—

Belfast Naturalists' Field Club, Museum, College Square, North.

Natural History and Philosophical Society, Museum, College Square, North.

Dublin—

Royal Dublin Society, Leinster House.

Royal Irish Academy, 19 Dawson Street.

Trinity College Library.

ITALY.

Milan—

Reale Istituto di Lombardo di Scienze, Lettere, ed Arti.

JAPAN.

Kyōto—

Imperial University, College of Science and Engineering.

Tokio—

Imperial University of Tokio, Science College.

JAVA.

Batavia—

Royal Magnetical and Meteorological Observatory.

MEXICO.

Mexico—

Instituto Geologico de Mexico.

Observatorio Astronómico Nacional de Tacubaya.

Observatorio Meteorologico-Magnetico Central.

Sociedad Científica "Antonio Alzate."

MONACO.

Monaco—

Musée Océanographique.

NETHERLANDS.

Amsterdam—

Académie Royale des Sciences à Amsterdam.

Harlem—

Musée Teyler.

Société Hollandaise des Sciences à Harlem.

Leyden—

Kon. Nederlandisch Aardrijkskundig Genootschap.

NEW ZEALAND.

Wellington—

New Zealand Institute.

NORWAY.

Christiania—

Kongelige Norske Frederiks Universitet.
Videnskabs-Selskabet i Christiana.

ROUMANIA.

Bucharest—

Societatiĭ de Sciinte Fizice.

RUSSIA.

Kazan—

Imperial Kazan University.

St. Petersburg—

Académie Impériale des Sciences.

SCOTLAND.

Aberdeen—

Philosophical Society, 147 Union Street.

Alnwick—

Berwickshire Naturalists' Club, *per* George Bolaur.

Edinburgh—

Advocates' Library.
Botanical Society of Edinburgh, Royal Botanic Garden.
Geological Society, 5 St Andrew Square.
Highland and Agricultural Society of Scotland, 3 George IV. Bridge.
Royal Physical Society, 18 George Street.
Royal Scottish Geographical Society, Queen Street.
Scottish Meteorological Society, 122 George Street.
Royal Scottish Society of Arts, 117 George Street.
Royal Society, The Mound, Princes Street.

Glasgow—

Archæological Society, 88 West Regent Street.
Baillie's Institution Free Library.
Faculty of Physicians and Surgeons of Glasgow, 242 St Vincent Street.
Geological Society, 207 Bath Street.
Glasgow University—
Glasgow and West of Scotland Technical College Library, 38 Bath Street
Institution of Engineers and Shipbuilders in Scotland, 207 Bath Street.
Mitchell Library, Miller Street.
Natural History Society of Glasgow, 207 Bath Street.
Stirling's Public Library, Miller Street.
West of Scotland Iron and Steel Institute.

Hamilton—

Mining Institute of Scotland.

SWEDEN.

Upsala—

Royal University Library.

Stockholm—

Kongliga Svenska Vetenskaps-Akademie.

TASMANIA.

Hobart—
Royal Society of Tasmania.

UNITED STATES.

Albany—
New York State Department of Health.
New York State Library.

Austin (Texas)—
Texas Academy of Science.

Baltimore—
Johns Hopkins University.

Berkeley (Cal.)—
University of California.

Boston—
American Academy of Arts and Sciences.
Boston Society of Natural History.
Library of the City of Boston, Copley Square.

Buffalo—
Buffalo Society of Natural Sciences.

Chicago—
Western Society of Engineers.

Colorado Springs—
Coburn Library, Colorado College.

Columbia (Mo.)—
University of Missouri.

Davenport (Iowa)—
Academy of Natural Sciences.

Denver—
Colorado Scientific Society.

Des Moines (Iowa)—
Iowa Geological Survey.

Indianapolis (Ind.)—
Indiana Academy of Science.

Lawrence (Kansas)—
Kansas University.

Madison (Wis.)—
Madison Geological and Natural History Society.
Washburn Observatory.

Mount Hamilton (Cal.)—
Lick Observatory.

Newhaven (Conn.)—
Connecticut Academy of Arts and Sciences.
Yale University.

UNITED STATES—*continued.*

New York—

American Geographical Society, 15 Eighty-first Street.

American Museum of Natural History, Seventy-seventh Street, and Central Park West.

American Society of Civil Engineers, 220 West Fifty-seventh Street.

New York Public Library, 40 Lafayette Place.

New York Academy of Sciences Library, Seventy-Seventh Street, Central Park, West.

School of Mines, Columbia College. The Associate Editor.

Philadelphia—

Academy of Natural Science of Philadelphia.

The Associated Alumni of the Central High School of Philadelphia.

American Pharmaceutical Association.

American Philosophical Society. The Hon. Secretaries, 104 South Fifth Street.

Franklin Institute, 15 South Seventh Street.

Numismatic and Antiquarian Society of Philadelphia.

Wagner Free Institute of Science, corner of Seventeenth Street and Montgomery Avenue.

Rochester (N.Y.)—

Rochester Academy of Science. Corresponding Secretary.

St. Louis—

Academy of Science of St Louis.

Missouri Botanical Garden.

Salem—

American Association for the Advancement of Science.

San Francisco (California)—

California Academy of Sciences.

Topeka (Kansas)—

Kansas Academy of Science.

Washington—

Bureau of Education (Department of the Interior).

Bureau of Ethnology.

Smithsonian Institution.

United States Geological Survey.

United States National Museum (Department of the Interior).

United States Naval Observatory.

United States (Department of Agriculture).

Volta Bureau.

LIST OF PERIODICALS.

(Those received in exchange are indicated by an "a").

WEEKLY.

Academy.
Architect.
Athenæum.
British Journal of Photography.
Builder.
Building News.
Chemical News.
Comptes Rendus.
County and Municipal Record.
*a*Deutsche Kolonialzeitung.
Dingler's Polytechnisches Journal.
Electrical Review.
Electrician.
*a*Engineering.
English Mechanic.
*a*Illustrated Official Journal of Abridgements of Patents.
*a*Journal of the Society of Arts.
Journal of Gas Lighting.
Lancet.
La Nature.
Nature.
Notes and Queries.
*a*Pharmaceutical Journal.
*a*Publishers' Circular.
Scientific American and Supplement.
Zeitschrift für Angewandte Chemie.

FORTNIGHTLY.

Annalen der Chemie (Liebig's).
*a*Berichte der Deutschen Chemischen Gesellschaft.
Journal de Pharmacie et de Chimie.
Journal für Praktische Chemie.

MONTHLY.

*a*American Chemical Journal.
American Journal of Science.
Analyst.
Annalen der Physik.
Annales de Chimie et de Physique.
Annales de l'Institut Pasteur.
Annales des Mines.
Annales des Ponts et Chaussées.
Annales des Sciences Naturelles—Botanique.
Annales des Sciences Naturelles—Zoologie.
Annals and Magazine of Natural History.
Antiquary.
Beiblätter zu den Annalen der Physik.
Bulletin de la Société Chimique de Paris.
Bulletin de la Société Géologique de France.
Bulletin de la Société Industrielle de Mulhouse.
Bulletin de la Société d'Encouragement pour l'Industrie Nationale.
Bulletin of the American Mathematical Society.
*a*Canadian Entomologist.

MONTHLY—*continued.*

*a*Engineering Review.
*a*Electrical Magazine.
*a*Geographical Journal.
Geological Magazine.
*a*Johns Hopkins University Circulars.
Journal of Botany.
*a*Journal of the Chemical Society.
Journal of Education.
*a*Journal of the Franklin Institute.
*a*Journal of the Royal Photographic Society.
*a*Journal of the Society of Chemical Industry.
*a*Journal of the Western Society of Engineers.
Library Association Record.
Library World.
London, Edinburgh, and Dublin Philosophical Magazine.
Petermanns Mitteilungen.
Polytechnic Bibliothek.
*a*Proceedings of the Royal Society of London.
*a*Proceedings of the Society of Biblical Archæology.
Revue Universelle des Mines.
*a*Royal Astronomical Society's Monthly Notices.
Science Abstracts.
*a*Science of Man.
*a*Scottish Geographical Magazine.
*a*Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
*a*Technics.
*a*Tijdschrift van het Koninklijk Nederlandoch Aardrijkskundig Genootschap.
*a*Travel.
Zoologist.
Zeitschrift fur Analytische Chemie.

QUARTERLY.

Annals of Botany.
Annals of Scottish Natural History.
*a*Archives Néerlandaises des Sciences Exactes et Naturelles.
*a*Bulletin of the American Geographical Society.
*a*Bulletin of the Kansas University.
Economic Journal.
Englische Studien.
Jahrbuch über die Fortschritte der Mathematik.
Journal of Anatomy and Physiology.
*a*Journal of the Anthropological Institute of Great Britain.
*a*Journal of Manchester Geographical Society.
*a*Journal of the Royal Institute of British Architects.
Journal of the Royal Microscopical Society.
*a*Journal of the Royal Statistical Society.
*a*Journal of the Scottish Meteorological Society.
*a*Memorias Y Revista de la Sociedad Científica "Antonio Alzate."
Mind: a Quarterly Review of Psychology and Philosophy.
*a*Proceedings of the American Philosophical Society.
Quarterly Journal of Economics.
Quarterly Journal of Geological Society.
Quarterly Journal of Microscopical Science.
*a*Quarterly Journal of Royal Meteorological Society.
Quarterly Journal of Pure and Applied Mathematics.
Reliquary and Illustrated Archæologist.
Record of Technical and Secondary Education.
Revue Historique.
*a*School of Mines Quarterly.
Scottish Historical Review.
Scientific Roll.

ANNUALLY.

Association Française pour l'Avancement des Sciences.
British Journal Photographic Almanac.
Hazell's Annual.
Jahres-Bericht Chemischen Technologie.
Journal of the Royal Agricultural Society of England.
L'Année Scientifique et Industrielle.
Murray's English Dictionary.
*a*Journal de L'École Polytechnique.
Palæontographical Society's Publications.
Philosophical Transactions, Royal Society of London.
Ray Society's Publications.
Repertorium der Technischen Journal—Litteratur.
Report of the Board of Education.
Statesman's Year Book.
Symons' British Rainfall.
Wright's English Dialect Dictionary.

The LIBRARY and the READING-ROOM are open:—Winter, 9.30 a.m. till 10 p.m. (except Saturdays); Saturdays, till 2 p.m.

Summer (May till October, except during the holidays, from the 11th till 31st July), 9.30 a.m. till 5 p.m.; Saturdays, till 1 p.m.

LIST OF MEMBERS

OF THE

Royal Philosophical Society of Glasgow

FOR 1904-1905.

HONORARY MEMBERS.

(*Limited to Twenty.*)

WITH YEAR OF ELECTION.

FOREIGN.

Rudolph Albert von Kölliker, Würzburg. - - - - 1860
Professor Ernst Heinrich Hæckel, Jena. - - - - 1880
Professor Georg Quincke, Hauptstrasse 47, Friederichsbau, Heidelberg. - - 1890
D. Ivanovitsch Mendeléeff, 19 Zabalkansky, St Petersburg. - - - - 1904

AMERICAN AND COLONIAL.

5 Robert Lewis John Ellery, F.R.A.S., Victoria, Australia. - - - - 1874
Thomas Muir, M.A., LL.D., F.R.S.S., L. and E., Superintendent General of Education, Cape Colony. - - - - 1892
Professor S. P. Langley, LL.D., D.C.L., Secretary of the Smithsonian Institution, Washington, U.S.A. - - - - 1895

BRITISH.

Sir Joseph Dalton Hooker, C.B., G.C.S.I., M.D., D.C.L., LL.D., F.R.S., The Camp, Sunningdale. - - - - 1874
Rev. John Kerr, LL.D., F.R.S., Glasgow. - - - - 1885
10 The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.S.G., Prof. of Nat. Philosophy in the Royal Institution, London, Terling place, Witham, Essex. - - - - 1890
The Right Hon. Lord Lister, O.M., LL.D., D.C.L., F.R.S., 12 Park crescent, Portland place, London, W. - - - - 1895
Sir Archibald Geikie, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom, 10 Chester terrace, Regent's Park, London, N.W. - - - - 1895
The Right Hon. Lord Kelvin, O.M., G.C.V.O., LL.D., D.C.L., F.R.S., Largs. 1896
(*Ordinary Member*, 1846 *till* 1896.)
Sir William T. Gairdner, K.C.B., M.D., LL.D., F.R.S., George sq., Edinburgh. 1900
(*Ordinary Member*, 1863 *till* 1900.)
15 Professor Edward Albert Schäfer, LL.D., F.R.S., M.R.C.S., University of Edinburgh. - - - - 1902
Sir William Huggins, K.C.B., D.C.L.Oxon., LL.D.Camb., Pres. R.S., F.R.A.S., etc., 90 Upper Tulse-hill, London, S.W. - - - - 1904
Sir William Ramsay, K.C.B., LL.D., D.Sc., Ph.D., F.R.S., Professor of Chemistry, University College, London, 19 Chester Terrace, Regent's Park, London, N.W. - - - - 1904

CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

A. S. Herschel, M.A., D.C.L., F.R.S., F.R.A.S., Hon. Professor of Experimental Physics in the University of Durham; Observatory House, Slough, Bucks. - 1874
Thomas E. Thorpe, Ph.D., F.R.S., F.R.S.E., Principal of the Government Laboratories, Clement's Inn-passage, W.C. - - - - - - - - - - 1874
John Aitken, LL.D., F.R.S., F.R.S.E., Ardenlea, Falkirk. - - - - - 1883
Alex. Buchan, M.A., LL.D., F.R.S.E., F.R.S., Secretary to the Scottish Meterological Society, 122 George street, Edinburgh. - - - - - - 1883
5 James Dewar, M.A., F.R.S., F.R.S.E., M.R.I., Jacksonian Professor of Physics, University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain, 1 Scroope terrace, Cambridge. - - - - - - - - 1883
Joseph W. Swan, M.A., D.Sc., F.I.C. F.C.S., M.I.Mech.E., Hon.M.I.E.E., F.R.S., 58 Holland Park, W. - - - - - - - - - - - 1883
William Milne, M.A., B.Sc., F.R.S.E., Department of Public Education, Cradock, Cape Colony. - - - - - - - - - - - - - 1894
Richard Lodge, M.A., Professor of History in Edinburgh University. - - - 1899
Edmund J. Mills, D.Sc, LL.D., F.R.S., Emeritus Professor of Technical Chemistry, Glasgow and West of Scotland Technical College, 64 Twyford avenue, West Acton, London, W. - - - - - - - - - - 1901
10 Arthur Schuster, Ph.D., F.R.S., Professor of Physics, Victoria University, Manchester, Victoria park, Manchester. - - - - - - - - - 1901
W. S. M'Cormick, M.A., LL.D., 2 St Andrew's square, Edinburgh. - - - 1902
John George Bartholomew, F.R.S.E., F.R.G.S., Geographical Institute, Park road, Edinburgh. - - - - - - - - - - - - - 1902
James Burgess, C.I.E., LL.D., F.R.S.E., Hon. A.R.I B.A., F.R.G.S., 22 Seton place, Edinburgh. - - - - - - - - - - - - - 1902
Francis Elgar, LL.D., F.R.S., F.R.S.E., 18 Cornwall Terrace, Regent's park, London, N.W. - - - - - - - - - - - - - 1902
15 Frederick Emley, Literary and Philosophical Society of Newcastle-upon-Tyne. - 1902
Professor Cargill G. Knott, D.Sc., F.R.S.E., 42 Upper Gray street, Edinburgh. 1902
Principal John Yule Mackay, M.D., LL.D., University College, Dundee. - - 1902
Professor John Millar Thomson, LL.D., F.R.S., F.I.C., F.C.S., King's College, and 9 Campden Hill Gardens, London, W. - - - - - - - - - 1902
Professor Robert Wallace, F.R.S.E, F.L.S., F.C.S., University of Edinburgh. - 1902

ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

a Denotes Life Members.

Adam, Stephen, 121 Bath street. 1896
*a*Adam, Thomas, F.S.I., 27 Union st. 1892
Adams, John, M.B., 1 Queen's crescent, W. 1902
Adams, William, Makerstoun, Bearsden. 1891
5 Addison, W. H., Superintendent Mount Florida Deaf and Dumb Institution. 1895
*a*Agar, Thomas F., Argentine Consul-General, 30 George square. 1896
Aikman, W. G., 12 Kingsborough gardens, Kelvinside. 1899
Aiton, Alexander Hamilton, 190 West George street. 1902
Alexander, D. M., 5 Derby crescent, Kelvinside. 1887
10 Alexander, G. W., M.A., 129 Bath street. 1893
Allen, Herbert Stanley, M.A., B.Sc., Blythswood laboratory, Renfrew. 1901
*a*Allan, Henry, 2 Park gardens. 1900
*a*Allan, James A., 25 Bothwell street. 1904
Allan, James W., M.B., 18 India street. 1900
15 Alison, John, M.A., F.R.S E., U.F.C. Training College. 1903
Alston, J. Carfrae, 9 Lorraine gardens. 1887
Anderson, Alexander, 157 Trongate. 1869
*a*Anderson, David H., Atlantic Mills, Bridgeton. 1904

Anderson, James, 4 Kingsborough gardens. 1900

20 Anderson, James, 168 George street. 1890

Anderson, James Scott, Auchnasith, Bearsden. 1902

Anderson, James Spencer, 81 Great Clyde street. 1901

Anderson, John, 142 West Nile st. 1884

Anderson, J. B. Mackenzie, M.B., 8 Buckingham terrace, Hillhead. 1895

25 Anderson, R. T. R., 80 Seedhill rd, Paisley. 1889

Anderson, Robert, 76 Bath street. 1896

Anderson, Robert, Eastwoodhill, Giffnock. 1900

*a*Anderson, Robert Locke, 233 St Vincent street. 1901

*a*Anderson, Sir T. M'Call, M.D., Professor of Practice of Medicine in the University of Glasgow, 9 The College. 1873

30 Anderson, Wm, 12 Princes square. 1900

*a*Anderson, William, 133 Wellington street. 1890

Anderson, W. F. G., 47 Union st. 1878

Andrew, Grant, 12 Woodside ter. 1900

*a*Andrew, James, 160 West George street. 1900

35 Andrews, H. W., 140 Hyndland road, Kelvinside. 1902

Angus, Robert, Lugar, Ayrshire, N.B. 1901

*a*Annan, J. Craig, 518 Sauchiehall street. 1888

Annandale, Charles, M.A., LL.D., 35 Queen Mary avenue. 1888

Arend, Waldemar, 1 Queensborough gardens. 1904

40 Arneil, Allan, Stewarton drive, Cambuslang. 1901

*a*Arnot, J. L., 204 Bath street. 1890

Arrol, Theodore A., Torwood Hill, Row, Dumbartonshire. 1902

Arrol, Wm. A., Torwoodhill, Row. 1869

*a*Arrol, Sir William, LL.D., Seafield, Ayr. 1900

45*a*Arthur, Andrew, 78 Queen street. 1902

*a*Arthur, James, 78 Queen street. 1900

Arthur, Sir Matthew, Bart., 78 Queen street. 1900

Arthur, Thomas G., Carrick house, Ayr. 1900

Bain, Andrew, 17 Athole gardens. 1890

50 Baird, Allan F., 192 St. Vincent street. 1904

*a*Baird, J. G. A., M.P., Wellwood, Muirkirk. 1892

*a*Balfour, Alexander, Kelvindare, Kelvinside. 1900

Ballantine, George, jun., 100 Union street. 1897

Ballantyne, John H., 212 Bath street. 1904

55 Barbour, Wm, M.B., C.M., 3 Edelweiss terrace, Partick. 1900

Barclay, A. J. Gunion, M.A., F.R.S.E., High School. 1893

Barclay, A. P., 133 St Vincent street. 1890

Barclay, George, 8 Windsor circus. 1891

Barclay, James, 16 Roxburgh street, Kelvinside. 1871

60 Barman, Harry D.D., 21 University gardens. 1904

Barnet, John, 73 Robertson street. 1901

*a*Barr, Archibald, D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow, Royston, Dowanhill. 1890

*a*Barr, James, C.E., I.M., F.S.I., 221 West George street. 1883

Barr, Patrick, 51 Bath street. 1902

65 Barr, Thos, M.D., F.F.P.S.G., 13 Woodside place, W. 1879

Barrett, Francis Thornton, Mitchell Library. 1880

Bauermeister, F., 49 Gordon street. 1901

Baxter, John, I.M., 243 St Vincent street. 1901

Baxter, W. R., 64 Great George street, Hillhead. 1900

70 Beardmore, W., Parkhead Forge. 1901

Beatson, George T., B.A. (Cantab.), M.D., 7 Woodside crescent. 1881

Beaumont, Frank, B.A. (Lond.), 19 Grantly gardens, Shawlands. 1904

Becker, L., Ph.D., Professor of Astronomy in the University of Glasgow, The Observatory. 1895

Beckett, Charles E., M.A., LL.B., 163 St Vincent street. 1903

75 Beckett, William, M.A., 225 West George street. 1900

Beedle, Peter D. Ridge, 166 Buchanan street. 1902

Begg, Wm, 636 Springfield road. 1883

Beilby, George T., F.I.C., 11 University gardens, Hillhead. 1895

Belhaven and Stenton, The Right Hon. Lord, Wishaw House, Wishaw. 1901

80 Bell, George, architect, 212 St Vincent street. 1900

*a*Bell, Henry, Mynthurst, Reigate, Surrey. 1876

Bell, Sir James, Bart, 135 Buchanan street. 1877

*a*Bell, James T., Woodbine, Blairmore, Argyleshire. 1896

*a*Bell, John J., Woodbine, Blairmore, Argyleshire. 1896

85*a*Bennett, Professor Peter, *Secretary*, 207 Bath street. 1900

Bennett, Robert J., Savoy park, Ayr. 1883

Bergius, Walter, C.E., 77 Queen st. 1897

*a*Biggart, Thomas, 105 West George street. 1900
*a*Bilsland, William, 28 Park circus. 1888
90 Binnie, Thomas, Junr., M.A., 3 Park Gate. 1903
*a*Birkmyre, John, Broadstone, Port-Glasgow. 1900
*a*Bishop, A. Henderson, Burncroft, Thorntonhall. 1896
Black, J. Albert, Lagarie, Row. 1869
Black, Malcolm, M.D., 5 Canning place. 1880
95*a*Black, William Dunn, J.P., Auchentoshan, Dalmuir. 1901
*a*Blackie, J. Alexander, 17 Stanhope street. 1881
*a*Blackie, J. Robertson, North Bank, Dowanhill. 1881
Blackie, W. G., Ph.D., LL.D., F.R.G.S., 1 Belhaven terrace, Kelvinside. 1841
*a*Blackie, Walter W., B.Sc., The Hill House, Helensburgh. 1886
100 Blackwood, Matthew, Ardmore, Port-Glasgow. 1901
Blair, J. M'Lellan, Williamcraig, Linlithgowshire. 1869
Blair, Matthew, Moorings, Thornly Park, Paisley. 1887
Blair, William, 24 St Vincent place. 1902
Bles, Edward J., B.A.(Cantab.), B.Sc.(Lond. and Vict.) Natural History Department, University of Glasgow. 1905
105 Blyth, Jas, M.A., LL.D., F.R.S.E., Professor of Natural Philosophy, Glasgow and West of Scotland Technical College, 204 George st. 1881
*a*Blyth, Robert, 1 Montgomerie quadrant. 1885
*a*Blythswood, The Rt Hon. Lord, Renfrew, *Hon. Vice-President.* 1885
Borthwick, James D., 46 Balshagray avenue, Partick. 1891
*a*Boston, Alex. L., 12 Argyle arcade. 1902
110 Bottomley, James T., M.A., D.Sc., F.R.S., F.R.S.E., F.C.S., 14 University gardens, Hillhead. 1880
Bottomley, Wm, C.E., 15 University gardens. 1880
Bower, F.O., D.Sc., M.A., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow, 1 St John's terrace, Hillhead. 1885
Bowers, John, *Depute* Town Clerk, City Chambers. 1904
*a*Boyne, James, 106 West Nile street. 1901
115 Boyd, John, Shettleston Iron-works, near Glasgow. 1873
*a*Broadfoot, William R., Inchholme Works, Whiteinch. 1900
Brodie, Wm Brodie, M.B., C.M., Worcestershire Sanatorium, Knightwick, near Worcester. 1897
Brodie, William, B.L., 77 St Vincent street. 1902
Bromhead, Horatio K., F.R.I.B.A., I.A., 18 Kirklee road, Kelvinside. 1901
120 Brown, Alex., The Craigs, Carmunnock. 1896
Brown, A. M., 22 West Nile street. 1900
Brown, George Arbuckle, M.B., C.M., D.P.H.(Camb.), 180 Hyndland road, Partick. 1900
*a*Brown, Hugh, 5 St John's terrace, Hillhead. 1887
Brown, James, 76 St Vincent street. 1876
125 Brown, John Armour, Moredun, Paisley. 1901
Brown, J. T. T., Kessiebank, Cambuslang. 1902
*a*Brown, Nicol Paton, 22 Belhaven ter. 1901
Brown, Richard, Writer, 166 St Vincent street. 1895
Brown, Robert, 19 Jamaica street. 1882
130 Brown, Thomas Mathieson, coalmaster, Ardnith House, New Cumnock, Ayrshire. 1901
Brown, Wm, F.S.A.A., F.S.I., 138 West Regent street. 1901
*a*Brown, Wm Stevenson, 67 Washington street. 1886
*a*Brown, William, 165 West George street. 1892
Brown, Robert, B.Sc., 45 Washington street. 1893
135 Brownlee, Jno., M.D., Glasgow Fever Hospital, Belvidere. 19 2
Brownlie, John Douglas, M.B., Ch.B., L.D.S., 10 Brandon place. 1901
Brownlie, J. Rankin, L.D.S. (Eng.), 220 West George street. 1892
Bruce, Alex., Clyne House, Pollokshields. 1901
Bruce, David, M.A., LL.B., 141 West George street. 1897
140 Bruce, John, Inverallan, Helensburgh. 1902
Bryce, John, Assoc. M.Inst.C.E., Maxwell street, Partick. 1900
Bryden, Robert A., F.R.I.B.A., F.S.I., 147 Bath street. 1872
*a*Buchanan, Andrew, Dunfillan, Helensburgh. 1902
*a*Buchanan, A. W. G., Parkhill, Polmont, Stirlingshire. 1903
145 Buchanan, George Douglas, Silverrae, Giffnock. 1901
Buchanan, Peter, 7 Garthland street. 1901
Buchanan, Robert Macneil, M.B., C.M., F.F.P.S.G., 2 Northbank terrace, Kelvinside. 1900

Buchanan, Walter, Clerkhill House, Dumbarton. 1901
*a*Buchanan, Wm. Enderley, Bearsden. 1886
150 Burnet, John James, A.R.S.A., F.R.I.B.A., 70 University avenue. 1892
Burns, J., M.D., 15 Fitzroy place, Sauchiehall street. 1864
Burns, James, 2 Caird drive, Partick. 1905
*a*Burrell, Wm, 54 George square. 1900
Burton, William L., 6 Richmond crescent, Glasgow. 1899
155 Burr, Robert A., M.A., 26 Barnwell terrace, Govan. 1904

Caird, Robert, LL.D., F.R.S.E., 56 Esplanade, Greenock. 1898
Calder, Wm Ramsay, 102 Hope street. 1901
*a*Caldwell, George B., Scotia Leather Works, Boden street. 1892
Caldwell, James, 6 Newton place. 1900
160 Cameron, Sir Hector C., M.D., Professor of Clinical Surgery, University of Glasgow, 200 Bath street. 1873
*a*Campbell Arch., Springfield quay. 1895
*a*Campbell, J. A., LL.D., M.P., Stracathro, Brechin. 1848
Campbell, James Murdoch, 147 George street. 1901
Campbell, John, 49 St Andrew's drive, Pollokshields. 1901
165*a*Campbell, John Ferguson, 2 Holborn terrace, N. Kelvinside. 1892
Campbell, John M., F.E.I.S., Kennedy St Public School, and 14 Royal crescent, Crosshill. 1900
Campbell, John MacNaught, C.E., F.Z.S., F.R.S.G.S, 6 Franklin terrace, Dumbarton road. 1883
Campbell, Malcolm, 18 Gordon street. 1894
Campbell, Joseph Dawson, 142 West George street. 1903
170*a*Campbell, Thomas, Maryhill Iron works. 1894
Campbell, The Right Reverend Archibald E., D.D., Bishop's House, Woodside terrace. 1904
Cant, James, Kilmeny, Ardrossan. 1901
Carmichael, Neil, M.D., C.M., F.F.P.S.G., Invercarmel, 23 Nithsdale drive, Pollokshields. 1873
Carswell, John, F.F.P.S.G., L.R.C.P.Ed., 5 Royal crescent, W. 1903
175 Carver, Thomas, A.B., B.Sc., D.Sc., C.E., 8 Windsor quadrant, Kelvinside. 1890
Cayzer, Herbert Robin, Gartmore, Perthshire. 1901
*a*Cayzer, Sir Charles W., M.P., 109 Hope street. 1886

Chalmers, A. K., M.D., D.P.H. (Camb.), 7 Buckingham terrace. 1892
Chalmers, James, I.A., 93 Hope st. 1884
180 Chalmers, P. MacGregor, I.A., F.S.A.Scot., 95 Bath street. 1891
*a*Chisholm, Sir Samuel, Bart., LL.D., 20 Belhaven terrace. 1890
Christie, James Roberton, M.A., LL.B., 3 Gloucester place, Edinburgh. 1903
*a*Christie, Henry W., 46 West George street. 1892
Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868
185 Christie, Wm. E., M.A., 47 Millbrae road, Langside. 1903
*a*Christison, George, 13 Cambridge drive. 1897
Chrystal, W. J., F.I.C., F.C.S., Shawfield Works, Rutherglen. 1882
Clanachan, John, 4 Lloyd street, Dennistoun. 1900
Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870
190 Clark, John, 9 Wilton crescent. 1872
Clark, John, M.A., 2 Kelvingrove terrace. 1897
*a*Clarke, James Ferguson Wylie, M.A., F.R.C.S.Ed., 24 Buckingham terrace, Edinburgh. 1900
Cleghorn, Alexander, 10 Whittinghame drive, Kelvinside. 1904
*a*Cleland, John, M.D., LL.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 1884
195*a*Coats, Archibald, Woodside, Paisley. 1900
Coats, John J., M.A., 27 Woodside place. 1900
*a*Cochran, Robert, 7 Crown circus, Dowanhill. 1877
Coghill, William C., 24 Douglas st. 1873
Colquhoun, Walter, M.A., M.B., C.M., 7 Stanley street, W. 1900
200 Colville, James, M.A., D.Sc., 14 Newton place. 1885
*a*Combe, James Russell, 10 Camphill avenue, Langside. 1895
*a*Connell, Charles Broadfoot, Scotstoun Shipbuilding Yard, Whiteinch. 1900
*a*Connell, James G., 44 St Enoch's square. 1900
Cook, William, 77 St Vincent street. 1900
205 Copland, Wm R., M.Inst.C.E., F.S.I., 146 West Regent street. 1876
Core, Wm, M.D., Stobhill Hospital, Springburn. 1891
Cormack, J. D., B.Sc., Prof. of Mechanical Engineering, University College, Gower street, London, W.C. 1898

Corrie, David, F.C.S., "Nobels," Polmont Station. 1902
Costigane, J. T. Stewart, Limekilns House, East Kilbride. 1889
210 Costigane, William, Clifton hall, Albert drive, Pollokshields. 1890
Coubrough, A. Sykes, Parklea, Blanefield, Strathblane. 1869
Coulson, W. Arthur, 47 King street, Mile-end. 1888
Couper, James, Craigforth House, Stirling. 1862
Couper, Sinclair, Moore Park Works, Helen street, Govan. 1896
215 Cowie, Archibald, 20 Blythswood square. 1900
Craig, T. A., C.A., 139 St Vincent street. 1886
*a*Crawford, R. C., 12 Derby crescent, Kelvinside. 1902
Cree, Thomas S., 21 Exchange sq. 1869
Crichton, James, 201 Nithsdale road, Pollokshields. 1892
220 *a*Crookston, George B., 188 St Vincent street. 1900
Crosbie, Warren, B.L., 141 St. Vincent street. 1904
Cross, Alexander, M.P., 14 Woodlands terrace. 1887
*a*Cruikshank, Robert Alexander, J.P., shipowner, Ardbeg, Kilmun. 1901
*a*Crum, Walter G., Dalnotter House, Old Kilpatrick. 1895
225 Crum, William G., Dalnotter House, Old Kilpatrick. 1896
Culbert, James, 12 Eildon Villas, Mount Florida. 1902
*a*Cullen, Alexander, F. R. S. E., F.R.I.B.A., 3 Blythswood square. 1901
*a*Curphey, Wm Salvador, Borva, Lenzie. 1883

Dalrymple, James D. G., F.S.A., Meiklewood, Stirling. 1902
230 *a*Daly, James, 2 Prince's gardens. 1898
*a*Dalziel, T. Kennedy, M.B., C.M., 196 Bath street. 1896
Dansken, A. B., 109 St. Vincent street. 1877
*a*Dansken, John, I.M., F.S.I., F.R.A.S., 241 West George street. 1876
Darling, William, 178 St Vincent street. 1901
235 Dewar, David, 11 Havelock street, off Byres road, Partick. 1903
Dick, Thomas, 166 St Vincent street. 1901
Dickie, John S., 30 Renfield street. 1900
*a*Dixon, James S., Fairleigh, Bothwell. 1900
Dixon, Walter, Derwent, Kelvinside gardens. 1893
240 Dobbie, A. B., M.A., 24 West Cumberland street. 1885
*a*Dobbie, Robert, Beechmount, Larbert. 1900
Docherty, P. Alpine, L.R.C.P., L.R.C.S.Edin., etc., 526 Springburn road. 1900
*a*Donald, James Addie, 12 Waterloo street. 1900
Donald, John, 23 Queen Margaret drive, N. Kelvinside. 1872
245 Donald, William, J. A., 16 Lilybank gardens. 1877
Dougall, Franc Gibb, 165 Canning street. 1875
Douglas, Campbell, I.A., F.R.I.B.A., 266 St Vincent street. 1870
Douglas, William M., 155 North street. 1903.
Downie, J. Walker, M.B., C.M., 4 Woodside crescent. 1901
250 Downie, Robert, jun., Carntyne Dyeworks, Parkhead. 1872
Downie, Thomas, Hydepark Foundry. 1886
*a*Dreghorn, David, Greenwood, Pollokshields. 1896
*a*Duncan, Eben., M.D., C.M., F.F.P.S.G., Queen's Park house, Langside road, *Hon. Vice-President.* 1873
Duncan, Hugh, M.A., LL.B., 54 West Nile street. 1895
255 Duncan, J. A., Aston, Bridge of Allan. 1896
*a*Duncan, Robert, Whitefield Works, Govan. 1890
Dunlop, David John, Inch Works, Port-Glasgow, and 198 Bath street. 1900
Dunlop, John, F.E.I.S., headmaster, Quarry Brae Public School, Parkhead. 1900
Dunlop, John, M.D., 1 Somerset place. 1900
260 *a*Dunlop, Nathaniel, 25 Bothwell st. 1870
*a*Dunlop, Thomas, 70 Wellington st. 1902
Dunn, Hugh Shaw, Earlston Villa, Caprington, Kilmarnock. 1901
Dunn, Robert Hunter, 4 Crown terrace, Dowanhill. 1878
Duthie, Andrew Drummond, 2 Rothesay Gardens, Partickhill. 1902
265 Duthie, James, 190 West George street. 1901
Dyer, Henry, M.A., D.Sc., C.E., 8 Highburgh terrace, Dowanhill. 1883
*a*Edington, George Henry, M.D., M.R.C.S. (Eng.), F.F.P.S.G., 225 Bath street. 1896
Edmiston, John C., M.D., F.F.P.S.G., 24 Wilton gardens. 1901

*a*Edwards, John, 4 Great Western terrace, west. 1883
270 Elliott, Joseph J., City Chambers. 1901
Erskine, Jas, M.A., M.B., L.F.P.S.G., 351 Bath street. 1886
Ewan, Thomas, M.Sc., Ph.D., 57 Montgomery street, Kirklee, Glasgow. 1901
Ewing, James C., 14 Woodlands road. 1902
*a*Ewing, Wm, *Vice President*, 45 Renfield street. 1883

275*a*Faill, John, 7 Winton drive, Kelvinside. 1901
Fairweather, Wallace, C.E., 62 St. Vincent street. 1880
Falconer, Patrick, 13 Sutherland street, Hillhead. 1876
Falconer, Thos, 50 Kelvingrove street. 1880
*a*Farquhar, Jas T., 47 Hope street. 1901
280 Farquhar, Wm R., St Malo, Kilmalcolm. 1892
Farrelly, John, 25 Elmbank crescent. 1901
Fawsitt, Charles A., 9 Foremount terrace, Partick. 1879
*a*Fergus, Freeland, M.D., F.R.S.E., F.F.P.S.G., *Hon. Secy.*, 22 Blythswood sq. 1887
Fergus, James, 58 York street. 1901
285*a*Fergus, Oswald, D.D.S., L.D.S., 12 Clairmont gardens. 1896
Ferguson, Alexr., 106 W. Regent street. 1901
Ferguson, David, Glenholm, Port-Glasgow. 1901
Ferguson, Fergus, 20 Royal terrace, West. 1900
Ferguson, George, 130 Bishop street, Port Dundas. 1904
290 Ferguson, James, Ingleneuk, Cathcart. 1897
*a*Ferguson, John, M.A., LL.D., F.R.S.E., Professor of Chemistry, University of Glasgow, *Hon. Vice-President*. 1869
Ferguson, John Forbes, 166 St Vincent street. 1895
Fife, William, jr, Fairlie, Ayrshire. 1901
Findlay, Joseph, Clairmont, Winton drive, Kelvinside. 1873
295 Finlayson, James, M.D., LL.D., 2 Woodside place. 1873
Fleming, Dr Robert H., 19 Newton street, Charing cross. 1901
*a*Fleming, E. Brown, Mambeg, Dumbartonshire. 1900
*a*Fleming, James, 136 Glebe street. 1880
*a*Fleming, John, 241 St Vincent street. 1900
300 Flower, Collingwood, Auchnacrioch, by Yoker, Renfrewshire. 1901
*a*Forrester, Henry, 105 West George street. 1900
Foster, W. A., St Catherines, Newlands road, Langside. 1899
Fotheringham, T. B., 52 Barrland street, Maxwell road. 1889
*a*Fowler, John, 2 Grantly gardens, Shawlands. 1880
305 Fraser, Melville, 31 St Vincent place. 1890
*a*Fraser, Thomas Smellie, F.S.I., 209 St Vincent street. 1900
*a*Fraser, Wm, F.S.I., 209 St Vincent street. 1900
Freebairn, J. B., M.A., Napiershall Public School. 1900
*a*French, Thomas, 1 Kelvinside ter. 1897
310 Frew, Alex., C.E., Assoc. M. Inst. C.E., 216 West George street 1876
*a*Frew, William, Ph.D., c/o H. Whiteway, Esq., The Orchards, Whimple, Devon. 1898
Fryers, Arthur John, 22 Bath street, Largs. 1899
Fullarton, Professor Robert, M.A., M.B., F.F.P.S.G., 276 Bath st. 1903
*a*Fullerton, Robt., M.D., 24 Newton place. 1896
315 Fulton, James, The Glen, Paisley. 1897
Fulton, James, 33 Hamilton drive, Hillhead. 1902
Fyfe, Alexander, 29 University avenue. 1897
Fyfe, A. Peden, 124 St Vincent street. 1900
Fyfe, Henry B., 115 St Vincent street. 1892

320*a*Gairdner, C. D., C.A., 115 St Vincent street. 1886
Galbraith, John Alexander, 28 Belhaven terrace. 1902
Galbraith, Peter, 4 Beaumont Gate, Dowanhill. 1889
Galbraith, Walter M., 7 Holyrood crescent. 1893
Galloway, T. Lindsay, C.E., 175 West George street. 1881
325 Galt, Professor Hugh, B.Sc., M.B., C.M., F.F.P.S.G., D.P.H.(Camb.), 14 Berkeley terrace, W. 1900
Gardiner, John, 18 Gibson street, Hillhead. 1901
Gardner, Daniel, 36 Jamaica street. 1869
Gardner, John, 146 Trongate. 1901
Gardner, John R., 33 Huntly gardens, Kelvinside. 1900
330*a*Garrett, Geo., Dunbeth lodge, Coatbridge. 190
*a*Garrow, James R., 6 Pollok road. 189

*a*Garroway, John, 694 Duke st. 1875
Gemmill, James Fairlie, M.A., M.D., Lecturer in Embryology, University of Glasgow. 1901
Gemmill, William, 62 Bath street. 1903
335 Gibson, Charles R., Lynton, Mansewood, by Pollokshaws. 1895
Gibson, William, 17 Wilton mansions. 1896
Gilfillan, Wm, 129 St Vincent st. 1881
*a*Gillies, William, 23 University gardens. 1901
Gillies, W. D., 17 Royal Exchange square. 1872
340 Glaister, John, M.D., F.F.P.S.G., D.P.H.(Camb.), F.R.S.E., F.C.S., &c., Professor of Forensic Medicine and Public Health, University of Glasgow, 3 Newton place, *Vice-President.* 1879
*a*Glaister, Joseph Newbigging, M.B., C.M., 5 Ronald street. 1900
*a*Glen, Lawrence, 165 St Vincent street. 1900
*a*Glen, Robert, Carlston, Kelvinside. 1901
Goldie, James, 52 St Enoch square. 1883
345 Goodwin, Robert, C.E., 3 Lynedoch street. 1875
Goold, James B., Bank of Scotland, Trongate. 1902
*a*Gordon, James, Stonebyres, 14 Aytoun road, Pollokshields. 1901
*a*Gourlay, Charles, B.Sc., A.R.I.B.A., Professor of Architecture, Glasgow Technical College, 30 Hamilton drive, Hillhead. 1900
Gourlay, Robert, LL.D., 5 Marlborough terrace. 1904
350 Gow, J. R., 32 Royal Exchange square. 1898
Gow, Leonard, 45 Renfield street. 1889
Gow, Leonard, jun., 45 Renfield street 1884
Gow, Robert, 3 Victoria circus, Dowanhill gardens. 1860
Graham, John Hatt Noble, Larbert House, Stirlingshire. 1900
355 *a*Graham, Robert, 108 Eglinton street. 1888
*a*Graham, William, B.L., 198 West George street. 1885
*a*Graham, William, C.A., 6 Royal crescent, W. 1900
Graham, Wm Edward Auld, 7 Royal Bank place. 1900
Grant, Rev. James Bell, B.D., 113 Hill street, Garnethill, St. Stephen's Parish Church. 1903
360 Graves, John William, Hydropathic, Kilmalcolm. 1901
Gray, Albert A., M.D., 14 Newton terrace. 1903
Gray, Andrew, 30 Bath street. 1889
Gray, Andrew, LL.D., F.R.S., Professor of Natural Philosophy in Glasgow University, *Vice-President* 1899
*a*Gray, Thomas, D.Sc., Ph.D., F.I.C., F.C.S., Professor of Technical Chemistry, Glasgow Technical College. 1904
365 *a*Gregory, Professor J. W., D.Sc, F.R.S., Glasgow University. 1904
Green, George, J.P., 40 Balshagray avenue, Partick. 1900
Greer, Thomas Arthur, Fairfield works, Govan. 1901
Greig, James R., Ravenswood, Crosshill. 1897
Grier, R. P., 54 Newark drive, Pollokshields. 1901
370 Grove, John, jun., 199 St Vincent st. 1902
Gumprecht, John, 8 Lyndoch street. 1900
Gunn, John, B.L., 144 Bath street. 1901
Gunn, N. B., F.F.A., F.I.A., President of the Faculty of Actuaries in Scotland, 35 St Vincent place. 1900
Guthrie, David Wm., 166 Buchanan street. 1900
375 Guthrie, John, 17 Whittinghame drive, Kelvinside. 1901

Hall, Colonel Peter Wishart, V.D., Arisaig, Craigendoran, Helensburgh. 1901
*a*Hamilton, John, I.A., 212 St Vincent street. 1885
Hanbidge, James E., 8 Balmoral crescent, Crosshill. 1897
Hannay, P. M., Bridge of Allan. 1898
380 Harington-Stuart, R. E. S. (Colonel), Torrance, East Kilbride, N.B. 1900
Harrington, John C., 14 Queen's Gate, Dowanhill. 1901
*a*Harrington, J. P., Broadfield, Port-Glasgow. 1900
Harris, F. W., 32 Kyle Park, Uddingston. 1900
Harrison, John, J.P., 7 Granby ter. 1900
385 *a*Hart, Robert, 8 Greenlaw Avenue, Paisley. 1902
Harvey, William Ure, Norman Hurst, Bearsden. 1896
Harvie, William, 8 Bothwell terrace, Hillhead. 1888
Hedderwick, Maxwell, 22 St Vincent place. 1892
*a*Henderson, A. P., 20 Newton place. 1880
390 Henderson, Francis, 47 Union street. 1901
Henderson, George G., M.A., D.Sc., F.I.C., F.C.S., Professor of Chemistry, Glasgow and West of Scotland Technical College, 204 George street. 1883

Henderson, John, Towerville, Helensburgh. 1890
*a*Henderson, Thomas, 1 Lancaster crescent, Kelvinside. 1900
Henderson, Thomas Beath, M.D., 25 Lansdowne crescent. 1899
395 *a*Henderson, William, 15 Cadogan street. 1873
Hendry, Geo. Scott, 310 St. Vincent street. 1895
Henry, R. W., 21 Oakfield terrace, W. 1875
Higgins, Henry, jun., 248 West George street. 1878
Hinshelwood, James, M.A., M.D., 26 Woodside place. 1896
400 Hinshelwood, Thomas, Kennyhill house, Dennistoun. 1903
Hogg, Robert, 163 Nithsdale road, Pollokshields. 1865
Holmes, Daniel T., B.A., Ingleholm, Bridge of Weir. 1898
Honeyman, P. S., 12 South Park terrace. 1900
*a*Hope, James, Dean house, Lenzie. 1898
405 Horne, Joseph, M.B., C.M., 5 Windsor street. 1900
*a*Houldsworth, J. H., Rozelle, Ayr. 1900
*a*Houldsworth, Wm Thos, Clerk in Holy Orders, 1 Mansfield street, Portland place, London, W. 1901
Houstoun, Wm Henry, Hillcrest, Cambridge drive. 1895
Howat, William, 37 Elliot street. 1885
410 *a*Hunt, John, Milton of Campsie. 1881
*a*Hunter, Richard H., Glentyan, Kilbarchan, Renfrewshire. 1900
Hunter, Robert, 72 Waterloo street. 1901
Hunter, Walter K., M.D., 7 Woodside place. 1899
*a*Hunter, Wm S., 70 Robertson street. 1889
415 Hutchison, John C., 8 Lansdowne crescent. 1900
Hutchison, Joseph, Woodside, Netherburn, Lanarkshire. 1901
Hutton, James, C.A., 203 West George street. 1897
Hutton, W. K., M.A., M.B., Senior Demonstrator of Anatomy, The University. 1900
*a*Hyslop, William, of Bank, New Cumnock. 1901

420 Inglis, John, LL.D., Pointhouse Shipyard. 1895
*a*Inglis, Malcolm, 48 St Andrew's square. 1900
Inglis, R. A., Culrain, Bothwell, 1889
Innes, Gilbert, 27 Hamilton drive, Hillhead. 1900
Inverclyde, Lord, The Right Hon., Castle Wemyss, Wemyss Bay. 1900
425 *a*Irons, Joseph Jones, Summerlea, Kilcreggan. 1902

Jack, William Robert, M.D., 43 Lansdowne crescent. 1899
*a*Jack, William, M.A., LL.D., Professor of Mathematics in the University of Glasgow. 1881
Jackson, Harold D., Easterhill, Helensburgh. 1902
Jackson, Robert, 16 Dixon avenue, Crosshill. 1902
430 Jackson, Thomas, C.A., 24 George square. 1900
Jamieson, Andrew, F.R.S.E., M.Inst.C.E., M.Inst.E.E., etc., 16 Rosslyn terrace, Kelvinside. 1881
Jenkins, James Graham, Airedale, Cambuslang. 1901
Jenkins, Thomas, Woodlands, Crosshill. 1901
Johnston, Alex., M.D. (Glasgow), D.P.H. (Camb)., Ruchill Hospital. 1900
435 Johnston, David, 160 West George street. 1891
Johnston, Jas., 1005 Garngad road, Provanmill. 1903
Johnston, Michael, 19 Waterloo street. 1903
Johnston, William G., Anchor Chemical Works. 1901
Jones, Arthur L., 1027 Sauchiehall street. 1905
440 Jubb, John, B.L., 190 West George street. 1902

Kay, Arthur, J.P., Tregortha, Winton drive. 1904
Kay, Cathcart, 77 St Vincent street. 1900
Kay, Thomas, M.B., C.M., 5 Rosebery terrace. 1899
Kean, James, 31 Scotia street, Garnethill. 1888
445 *a*Kelly, Alexander, 100 Hyde Park street. 1901
Kelly, Hugh, M.D., Catrine Bank, Shields road, Pollokshields. 1898
Kelly, J. H., J.P., Parkhead. 1900
Kelly, James K., M.D., F.F.P.S.G., Park villa, Queen Mary avenue, Crosshill. 1889
Kelly, John Davidson, M.A., Stanley house, Bridge-of-Allan. 1901
450 Kemp, Wm (Alexander, Fergusson, & Co., Ltd), Ruchill, Maryhill. 1898
*a*Kennedy, Alexander, Kenmill House, Bothwell. 1902
Kennedy, James, 43 Greendyke st. 1889
Kennedy, Ballie John, Airdrie. 1904

*a*Kennedy, Moses Hunter, 217 West George street. 1901
455*a*Kennedy, William, Partick, 13 Victoria crescent, Dowanhill. 1900
*a*Ker, Charles, M.A., C.A., 115 St Vincent street. 1885
*a*Ker, Wm, 1 Windsor terrace, Kelvinside, West. 1874
Kerr, Geo. Munro, 34 West George street. 1890
Kerr, John G., M.A., LL.D., 15 India street. 1878
460 Kerr, J. Graham, M.A., Professor of Zoology University of Glasgow, 15 Clarence dr., Hyndland. 1904
Kerr, William, 260 West George st. 1902
Kidston, Geo. J., Finlaystone, Langbank. 1900
*a*Kidston, William H., 81 Great Clyde street. 1900
*a*Kiep, Johannes N., Imperial German Consul, 137 West George street. 1900
465*a*King, Chas M., Antermony house, Milton of Campsie. 1900
King, Sir James, Bart, LL.D., of Campsie, 115 Wellington street. 1855
King, John, 17 Queen's crescent. 1895
King, John C., 21 Newton place. 1898
King, Professor L. A. L., 8 Ardgowan terrace, Sandyford. 1905
470 Kirk, Robert, M.D., Newton cottage, Partick. 1877
Kirk, Rev. Edward Bruce, E.U. Manse, Barrhead. 1905
Kirkpatrick, Alexander B., 88 St Vincent street. 1885
Kirkwood, James, Carling lodge, Ibrox. 1890
Knight, James, M.A., D.Sc., F.C.S., F.G.S., F.E.I.S., The Shieling, Uddingston. 1893
475 Knight, John, M.D., D.P.H. (Camb.), 4 Linn terrace, Cathcart. 1900
*a*Knox, David J., 19 Renfield street. 1890
Knox, John, Finnieston School. 1900
*a*Knox, John, 13 Montgomerie quadrant, Kelvinside. 1902

Laird, John, Royal Exchange Sale Rooms. 1879
480 Lamb, David, 155 Hyndland road. 1896
Lamberton, Alex., 8 Adelphi ter. 1900
Lamberton, Andrew, Blairtummock, Easterhouse. 1904
Lamberton, Hugh Alexander, Lylestone, Pollokshields. 1901
*a*Lamberton, Hugh, 8 Adelphi ter. 1900
485 Lambie, Robert, Strathview, Larkhall. 1901
Lamond, Robert, M.A., LL.B., 163 West George street. 1894
Lamont, Alexander, Kelvinhaugh Public School, 10 Ardgowan terrace, Sandyford. 1900
Lang, William, F.C.S., Crosspark, Partick. 1865
Lang, W. R., D.Sc., F.I.C., F.C.S., Professor of Chemistry in the University of Toronto, Canada. 1899
490*a*Langlands, E. W., 113 West Regent street. 1902
*a*Lauder, James, F.R.S.L., Glasgow Athenæum. 1892
*a*Lauder, John, 46 Gordon street. 1894
Laughland, David, Linwood House, Linwood, Renfrewshire. 1901
Laurie, Malcolm, B.A., D Sc., F.L.S., Professor of Zoology (St Mungo's College), Clunaline, Lenzie. 1901
495 Law, James H., Brandon House, Ibrox. 1901
Law, John, R. K., 20 Ashton gardens, Dowanhill. 1896
*a*Lawson, Thomas, Birchgrove, Pollokshields. 1901
Lee, William, M.A., F.E.I.S., teacher, 2 Tantallon terrace, Ibrox. 1901
Leipper, James, 12 Park drive, 1901 Whiteinch. 1902
500*a*Lindsay, Archd M., M.A., 87 West Regent street. 1872
*a*Lindsay, John, Conylea, Westbourne gardens, Kelvinside. 1902
Lochhead, Dugald Ferguson, 45 Cecil street, Hillhead. 1902
Logan, James, Grammar School, Uddingston. 1902
Lothian, A. Veitch, M.A., B.Sc., F.R.S.E., Lecturer, 25 Lilybank Gardens. 1891
505 Love, James Kerr, M.D., C.M., 173 Bath Street. 1888
Love, Wm., 28 Royal Exchange sq. 1901
*a*Low, Isaac, 60 Weaver street. 1898
*a*Lumsden, Harry, M.A., LL.B., 105 West George street. 1900
Lundholm, C. O., Nobel's Explosives Factory, Ardeer, Stevenston. 1890

510 M'Ara, Alexander, 65 Morrison st. 1888
Macara, James, 19 Waterloo street. 1901
Macara, Mudie, 1 Belmont street. 1901
M'Arly, Thomas, 29 W. George st. 1897
*a*M'Arthur, John S., 74 York street. 1890
515 M'Ausland, William F., 51 Buchanan street. 1903
Macaulay, C. E. (Colonel), 1901
Macbean, Ed, F.R.G.S., F.R.S.L., 31 Athole gardens. 1901
M'Bryde, Peter, M.B., 18 Queen's crescent, W. 1900

M'Calman, George, 1 India street, W. 1905

520 *a*M'Callum, Hugh, M.A., 7 Bute Mansions, Hillhead. 1902

*a*M'Callum, Robert, junr., 69 Union street. 1891

*a*M'Clelland, Andrew Simpson, C.A., 4 Crown gardens, Dowanhill. 1884

M'Conville, John, M.D., 14 Parkgrove terrace. 1870

M'Cosh, Andrew K., Cairnhill, Airdrie. 1901

525 *a*M'Cowan, David, jun., 9 Crown circus place. 1898

M'Cracken, James, 5 Bowmont terrace, Kelvinside. 1889

M'Crae, John, 7 Kirklee gardens, Kelvinside. 1876

M'Creath, James, M.E., 208 St Vincent street. 1874

M'Culloch, Hugh, 134 West Regent street. 1880

530 M'Donald, Alexander Beith, M.Inst. C.E., city engineer, City Chambers. 1901

MacDonald, Charles, 152 Cromwell road, Crosshill. 1902

*a*M'Donald, John, 72 Great Clyde street. 1896

Macdonald, John King, J.P., Whittingham drive, Kelvinside. 1900

*a*Macdougall, Robert, F.S.A.A., F.S.I., 138 West Regent street. 1900

535 M'Elligott, John, 4 Victoria drive, Mount Florida. 1901

*a*M'Ewen, Robert, 11 Park terrace. 1900

*a*Macfarlane, Walter, 22 Park circus. 1885

M'Farlane, Wm, Edna Lodge, Rutherglen. 1888

*a*M'Gilvray, R. A., 129 West Regent street. 1880

540 M'Gregor, A. N., M.D., 121 Douglas street. 1900

MacGregor, D. O., M.D., Victoria Infirmary. 1904

*a*Macgregor, R. D., 137 West George street. 1900

Machell, Thomas, 1 Burnbank ter. 1886

*a*Macindoe, Alex., 104 West George street. 1894

545 Macintyre, John, M.B., C.M., 179 Bath street. 1895

*a*M'Intyre, T. W., 21 Bothwell st. 1900

M'Intyre, Wm, F.E.I.S., Appin, Melrose avenue, Rutherglen. 1901

Mackay, R. C., 82 West Regent st. 1903

M'Kean, Francis, 235 Bath street. 1903

550 *a*M'Kechnie, D., 14 Candleriggs. 1900

M'Kellar, John C., 45 West Nile street. 1896

M'Kellar, J., 25 Kelvinside terrace. 1893

*a*M'Kendrick, John G., M.D., C.M., LL.D., F.R.S., F.R.S.E., F.R C.P.E., Professor of Physiology in the University of Glasgow, 2 Buckingham terrace, *Hon. Vice-President.* 18

M'Kendrick, J., Souttar, M.D., F.R.S.E., 2 Buckingham terrace. 19

555 Mackenzie, John Alexander, M.B., C.M., 7 Sinclair drive, Langside. 19

Mackenzie, Thomas Riach, 16 Robertson street. 19

*a*M'Kenzie, W. D., 43 Howard street. 18

M'Kie, John, M.B., C.M., 24 Hillside terrace. 18

Mackillop, Fred. G., M.A., LL.B., 208 St Vincent street. 19

560 *a*Mackinlay, James Murray, The Lee, Merchiston, Edinburgh, 18

*a*Mackinlay, J. T. C., 210 Nithsdale road, Pollokshields. 19

*a*Mackinlay, R. W., 52 Aytoun road, Pollokshields. 19

Mackintosh, Donald J., M.B., C.M., Western Infirmary, 18

*a*Mackinnon, John, 22 Carmichael street, Govan. 19

565 Mackinnon, William, C.A., 34 West George street. 19

MacLachlan, Dugald, B.L., 30 Renfield street. 19

Maclae, A. Crum, 192 St Vincent street. 18

M'Laren, Robert, Royal Bank, Garscube cross. 18

MacLaurin, Robert, 13 Claremont gardens, Milngavie. 18

570 M'Lay, James, C.A., 94 Hope street. 19

Maclay, W., Thornwood, Langside. 18

M'Lean, Angus, B.Sc., C.E., Principal, Technical School, Paisley. 18

Maclean, A. B., Craigpark Works, Flemington street, Springburn. 18

M'Lean, Charles R., L.R.C.P.E., L.R.P.S.G., 12 Annfield place, Dennistoun. 19

575 Maclean, Magnus, M.A., F.R.S.E., D.Sc., Professor of Electrical Engineering, Glasgow and West of Scotland Technical College, 51 Kersland terrace, Hillhead, *Vice-President.* 18

*a*MacLehose, James J., M.A., 61 St Vincent street. 18

MacLellan, Lewis, 5 Bowmont gard. 18

*a*Maclellan, Peter, Glasgow Rubber Works, Maryhill. 19

*a*Maclellan, Wm. Walter, 3 Montague terrace, Kelvinside. 19

580 *a*Macleod, A., 54 Tytherton road, Treefall park, London, N. 18

*a*Macleod, Frederick Larkins, 142 St. Vincent street. 1901
Macleod, the Rev. Donald, B.A., D.D., 1 Woodlands terrace, 1900
M'Michael, Thomas, M.A., B.Sc., 54 Windsor street. 1901
M'Millan, A. Lewis, M.D., C.M., 1 Rosebery terrace, Great Western road. 1897
585 M'Millan, Archibald, 5 Whittinghame gardens. 1899
M'Millan, Robert, Methlan park, Dumbarton. 1901
*a*Macnab, James, Lilyburn, Milton of Campsie, Stirlingshire. 1901
Macnair, John, 130 Claythorn street, and 1 Morris place, Monteith row. 1900
Macnair, Matthew, 1 Morris place, Monteith row. 1901
590 Macphail, Donald, M.D., Garturk cottage, Whifflet, Coatbridge. 1877
Macpherson, Duncan, Rosemount School. 1900
Macquaker, Thomas, 89 West Regent street. 1902
M'Raith, James N., 4 Queen's square, Strathbungo. 1900
M'Vail, D. C., M.B., Professor of Clinical Medicine, St Mungo's College, 3 St James' terrace, Hillhead. 1873
595 M'Vail, John C., M.D., D.P.H. (Camb.), 20 Eton place, Hillhead. 1904
*a*Macwhannell, Ninian, 58 West Regent street. 1898
M'Whirter, W., 3 Albany street, Kelvinside. 1901
Main, Robert B., Lyndhurst, 1 Winton drive, Kelvinside. 1885
Malloch, A. M., Firhill, Garscube road. 1896
600*a*Mann, James, 4 University gardens. 1900
*a*Mann, John, C.A., 142 St Vincent street, *Hon. Treasurer.* 1856
*a*Mann, John, jun., M.A., C.A., 142 St Vincent street 1885
Mann, Ludovic MacLellan, 142 St Vincent street. 1897
*a*Mann, Robert M., 3 Montgomerie crescent. 1900
605 Manwell, James, The Hut, 4 Albert drive, Pollokshields. 1876
Marks, Samuel, 145 Great Eastern road. 1884
Marr, John, J.P., Dunjarg, Bellahouston, Govan. 1900
Marr, Hamilton Clelland, M.D., Woodilee Asylum, Lenzie. 1899
Marshall, James, Woodcroft, Crow road, Partick. 1900
610*a*Marshall, Robt., 97 Wellington street. 1900
Martin, Jas F., 63 Brunswick st. 1895
Martin, John, writer, 58 West Regent street. 1901
Martin, Robert, 16 Ann street, Hillhead. 1897
Martin, William, 63 Brunswick st. 1903
615 Marwick, Sir J. D., LL.D., F.R.S.E., 19 Woodside terrace. 1878
Mathie, George M., 15 Dunard road, Rutherglen. 1895
Mathieson, J. H., 6 Park circus place. 189
*a*Mathieson, T. O., 6 Park circus place. 1896
Mavor, Henry A., 47 Broad street, Mile-end. 1887
620 Mavor, Samuel, 37 Burnbank gard. 1890
May, A. H., 15 Athole gardens. 1898
Meares, H. P., 34 Ancaster drive, Jordanhill. 1902
Mechan, Arthur, Scotstoun Ironworks. 1876
Mechan, Henry, Scotstoun Iron Works, Scotstoun. 1879
625 Medley, Dudley J., Professor of History in Glasgow University, 6 University gardens. 1901
Menzies, William Crawford, City Improvement Trust, 22 King st. 1895
Metcalfe, John Ramsay, 19 Montgomery quadrant. 1901
Millar, D. S., 144 St Vincent street. 1887
Millar, James, 152 Parliamentary road. 1870
630 Millar, Robert, 2 Rosslyn terrace, Kelvinside. 1903
*a*Miller, Alexander Wingate, 79 West Nile street. 1900
Miller, Alexander, junr., Dalmuir House, Dalmuir. 1899
*a*Miller, Arch. Russell, Hillpark, Bothwell. 1884
Miller, David S., 144 St. Vincent street. 1887
635*a*Miller, George, Surrey House, Victoria Embankment, London, W.C. 1881
Miller, G. J., Frankfield, Shettleston. 1888
Miller, Hugh, M.A., F.E.I.S., 2 Bogton Avenue, Cathcart. 1901
Miller, James, 5 Hanover street. 1900
*a*Miller, J. C., 40 West Nile street. 1900
640*a*Miller, Thomas Hodgson, Westcroft, Cleveland Walk, Bath. 1901
*a*Mirrlees, William J., 45 Scotland street. 1889
Mitchell, Alexander Brown, Avon Bank house, Larkhall. 1901
*a*Mitchell, Alex. Moncrieff, 8 Kew terrace, Kelvinside. 1903
Mitchell, Andrew, C.A., The Glasgow District Subway Co., St Enoch square Station. 1896

645*a*Mitchell, Andrew Acworth, 7 Huntly gardens. 1903
*a*Mitchell, George A., F.R.S.E., 5 West Regent street. 1883
Mitchell, Wm James, M.A., B.L., 48 West George street. 1897
*a*Moffatt, Alexander, 23 Abercromby place, Edinburgh. 1874
Mollison, James, 30 Balshagray aven., Partick. 1889
650*a*Mond, Robert Ludwig, B.A. (Cantab.), F.R.S.E., 20 Avenue rd., Regent's park, London, N.W. 1890
*a*Monro, T. K., M.A., M.D., F.F.P.S.G., Professor of Medicine in St Mungo's College, 10 Clairmont gardens. 1897
*a*Monteith, Robert, Greenbank, Dowanhill gardens. 1885
Moore, Alexander, C.A., 6 Lancaster crescent, Kelvinside. 1869
Moore, Alexander George, M.A., B.Sc., 13 Clairmont gardens. 1886
655*a*Moore, Robert Thomas, D.Sc., 13 Claremont gardens. 1904
Morrice, Jas A., 1 Prince's ter., Dowanhill. 1883
*a*Morton, George, Horslethill road, Kelvinside. 1902
Morton, James S., 118 Queen st. 1903
Motion, James Russell, 266 George street. 1887
660 Motion, Thomas Mason, 6 Melrose street, Great Western road. 1897
Muir, Alexander, 134 Nithsdale road, Strathbungo. 1883
*a*Muir, Allan, Ardmay, Newlands road, Langside. 1881
Muir, James, D.Sc., M.A., 189 Renfrew street. 1904
Muir, Matthew Greenlees, 12 Waterloo street. 1901
665 Muir, Robert, M.D., F.R.C.P.E., Professor of Pathology in Glasgow University, 16 Victoria crescent, Dowanhill. 1899
*a*Muirhead, Andrew Erskine, Cart Forge, Cathcart. 1873
Muirhead, James, 2 Bowmont gardens, Kelvinside. 1887
*a*Muirhead, Robert F., M.A., D.Sc., 24 Kersland street, Hillhead. 1879
Munro, Alexander, M.B., C.M., 12 Seton Terrace, Dennistoun. 1900
670 Munro, Daniel, F.S.I., 10 Doune terrace, Kelvinside. 1867
*a*Munro, Donald Mackay, 88 St Vincent street. 1901
Munro, J. M. M.. M.Inst. E.E., M.Inst.C.E., F.R.S.E., 136 Bothwell street. 1896
Murdoch, George, 40 St Vincent place. 1894
Murdoch, John, 208 West George st. 1901
675*a*Murdoch, Robert, 91 Maxwell road. 1880
Murray, Charles Robert, Woodbank, Partickhill. 1902
*a*Murray, Daniel, 5 Wilton crescent. 1896
*a*Murray, David, LL.D., 169 West George street, *President.* 1876
Murray, John Bruce, 24 George square. 1890

680 Napier, Alex., M.D., F.F.P.S.G., Rose Bank, Queen Mary avenue, Crosshill. 1886
Napier, Robert T., 75 Bothwell street, Glasgow. 1899
*a*Neilson, George, LL.D., Pitlochie, 11 Annfield terrace, Partick, *Vice-President.* 1897
*a*Neilson, James, 116 Bishop street, Port-Dundas. 1896
*a*Neilson, John, Mollance, Castle-Douglas. 1900
685*a*Neilson, Walter, Ewenfield, Ayr. 1900
Nelson, Alex., 63 North Frederick street. 1880
*a*Nelson, John E., 26 Queen street. 1900
Nelson, Thos C., Craiglea, Dennistoun. 1900
Ness, James, M.A., LL.B., 216 West George street. 1904
690 Ness, Professor R. Barclay, M.A., M.B., 19 Woodside place. 1902
*a*Newlands, Joseph F., 105 West George street. 1883
Nicol, James Monro, 93 Cheapside street. 1901
*a*Nicoll, James H., M.B., 4 Woodside place. 1897
Nisbet, Thomas, M.Inst.C.E., Master of Works, City Chambers. 1902
695 Nish, Robert, 9 Claremont terrace. 1897

Orr, George Smith, 139 St Vincent street. 1901
Orr, John, 101 Wellington street. 1901
Orr, Robert, 79 West Nile street. 1890
*a*Osborne, Hugh, 4 Kew terrace, Glasgow. 1899
700*a*Oswald, Dr Landel Rose, Glasgow Royal Asylum. 1902

Park, James, 51 Milburn street. 1877
*a*Park, Colonel J. Smith, V.D., 20 Park terrace. 1900
Park, Robert, M.D., 40 Grant st. 1894
Parker, Edward H., 11 Strathmore gardens, Hillhead. 1897
705*a*Parker John Dunlop, C.E., 146 West Regent street. 1889

Parker, James H., B.L., C.A., 89 West Regent street. 1900
*a*Parnie, William, 27 Union street. 1897
Parry, Robert Henry, F.R.C.S.E., 25 Blythswood square. 1900
*a*Paterson, Robert, C.A., J.P., 105 West George street. 1881
710 Paterson, Wm., M.B., C.M. (Edin.), 43 Millbrae Road, Langside. 1902
Paton, James, F.L.S., Glasgow Art Gallery and Museum, Kelvingrove. 1876
Patrick, Joseph, M.A., C.A., 203 West George street. 1893
Patrick, Joseph, of Alex. Kay & Co., Royal Exchange buildings. 1900
Patterson, T. L., F.C.S., Maybank, Finnart street, Greenock. 1873
715 Pearce, C. W. Bream, Nithsdale, Maitland avenue, Langside. 1903
Petrie, Alexander, I.A., 134 Wellington street. 1885
Petrie, John W., 4 Garrioch drive, Kelvinside, N. 1900
Pettigrew, Andrew H., 3 Claremont terrace. 1902
*a*Picken, David Kennedy, B.A., Ashburne, Partickhill. 1903
720 Pinkerton, Surgeon Major General, M.D., K.H.P., Queen's Park House, Langside. 1900
*a*Pirrie, Robert, 9 Buckingham ter. 1875
Playfair, David James, 7 Victoria crescent, Dowanhill. 1901
Pollock, A. Barr, M.B., C.M., 3 Belgrave terrace, Hillhead. 1897
*a*Pollock, R., M.B., C.M., F.F.P.S.G., Laurieston house, Pollokshields. 1883
725 Procter, Robert, Claremont, Alloa. 1901
*a*Provan, James, 92 West Nile st. 1868
Provand, A. D., M.P., 2 Whitehall court, London, S.W. 1888

Raalte, Jacques Van, c/o M. Van Raalte, Esq., 22 Austen Friars, London, E.C. 1884
*a*Ralston, William Henry, 4 North Court, Royal Exchange. 1900
730 Ramsay, G. G., LL.D., Litt. D., Professor of Humanity in Glasgow University, 6 The College. 1900
Ramsey, Robert, 14 Park terrace. 1889
*a*Ramsey, Robert, junr., 14 Park ter. 1898
Rankin, The Rev. W. M., B.D., clergyman, 8 Craigpark, Dennistoun. 1900
Rankine, Adam, Rolandseek, Bridge of Weir. 1901
35 Rankine, David, C.E., 238 West George street. 1875
*a*Reid, Andrew Thomson, 10 Woodside terrace. 1900
Reid, David, 16 Cambridge street. 1887
*a*Reid, Hugh, Belmont, Springburn. 1880
*a*Reid, James A., Dean of Faculty of Procurators, 172 St Vincent street. 1904
740 Reid, James, 15 Montgomerie crescent. 1886
*a*Reid, Joseph, 32 Newark drive, Pollokshields. 1901
*a*Reid, Nicholas M'Whirter, 7 Oakley terrace, Dennistoun. 1901
Reid, Robert, C.A., 40 St Vincent place. 1900
Reid, Thos, M.D., LL.D., 11 Elmbank street. 1869
745 Reid, William, M.A., 61 Grant street. 1881
*a*Reid, Walter M. N., 10 Woodside terrace. 1904
*a*Reid, William L., M.D., 7 Royal crescent, West. 1882
Renton, James Crawford, M.D., L.R.C.P. & S.Ed., 1 Woodside terrace. 1875
*a*Rennie, John, Wellcroft, Helensburgh. 1901
750 *a*Renwick, Wm, Langgarth, Stirling. 1901
Richmond, Thos, L.R.C.P.E., 4 Burnbank gardens. 1887
Rigg, R. A., 95 Buchanan street. 1900
Robb, George, carting superintendent, Caledonian Railway. 1901
Robb, William, F.R.C.V.S., 6 Canning place, Stirling road. 1900
755 *a*Roberton, William, 223 Sauchiehall street, Glasgow. 1899
*a*Robertson, Henry Tod, Meadowbank, Airdrie. 1901
Robertson, John, Endcliffe, Langside, *Hon. Librarian.* 1860
Robertson, J. M'Gregor, M.A., M.B., C.M., 26 Buckingham ter., Hillhead. 1881
Robertson, Mure, M.E., 4 Clairmont gardens. 1897
760 *a*Robertson, Robert, B.Sc., M.Inst. C.E., M.I.E.E., etc., 154 West George street. 1900
Robertson, Robert H., Clyde bank, Rutherglen. 1888
Robertson, Wm, 15 Gordon street. 1900
Rodger, Anderson, Glenpark, Port-Glasgow. 1899
Roemmele, C. H., 34 Kelvinside gardens. 1900
765 *a*Rogers, John C., 204 Bath street. 1888
Rose, Alexander, Richmond house, Dowanhill. 1879
Rose, Hugh, 26 Eglinton drive. 1900
*a*Ross, John 9 Westbourne gardens. 1885
Ross, John, Munn, C.A., 117 Wellington street. 1894

770 Ross, Russell James, manager, Parkhead Steel Works, 7 Ashfield gardens, Jordanhill. 1901
*a*Rottenburg, Paul, LL.D,. 55 West Regent street. 1872
Rowan, James, 22 Woodside place. 1897
Rowan, John, M.B., F.F.P.S.G., 10 Woodside crescent. 1900
Rowan, W. G., 234 West George street. 1881
775*a*Rowley, Thos, Campbell street, Govan. 1901
Runciman, Alexander, 45 Renfield street. 1900
Russell, James, c o Cluness, 25 Woodside quadrant. 1904
Russell, Robert, M.E., Coltness Iron Co., Ltd., Newmains, Lanarkshire. 1901

Salmon, W. Forrest, F.R.I.B.A., 53 Bothwell street. 1870
780*a*Samuel, John Smith, F.R.S.E., J.P., secretary to the Lord Provost of Glasgow, City Chambers. 1901
Sandeman, B., Ferndean, Lenzie. 1900
Sandilands, Robert Douglas, 4 Jane street, Blythswood square. 1902
Sawers, William D., Assoc.I.C., Athole Garden place. 1894
Sayers, William Brooks, M.I.E.E., 189 St Vincent street. 1890
785 Scott, Alexander, M.D., 2 Newton place. 1900
Scott, Alex., 34 Lawrence street, Dowanhill. 1871
*a*Scott, D. M'Laren, 2 Park quadrant. 1881
Scott, John, 249 West George street. 1892
Scott, Robert, I.M., 115 Wellington street. 1884
790*a*Service, Edward, 92 St Vincent street. 1901
Service, R. Gibson, 14 Royal Exchange buildings. 1900
*a*Service, William, 1 Queen's gate, Dowanhill. 1900
Sexton, A. Humboldt, F.C.S., F.I.C., F.R.S.E., Professor of Metallurgy, Glasgow and West of Scotland Technical College, 204 George street. 1892
Shand, F. J., 4 Bowmont gardens, Kelvinside. 1903
795*a*Shanks, J. B., 46 Gordon street. 1900
Shanks, John Cochrane, 103½ St Vincent street. 1899
*a*Shaw, A. M'Innes, Dunard, Sydenham, Dowanhill. 1900
Shaw, William, Ivy Lodge, Dullatur. 1900
*a*Shearer, Wm., 108 St Vincent st. 1901

800*a*Sherriff, George, Carronvale, Larbert, Stirlingshire. 1900
Shields, Daniel, 104 West George street. 1900
Simons, Michael, 2 Kensington gate. 1880
*a*Simpson, J. C., M.D., 9 Marlborough terrace, Kelvinside. 1896
Sloan, Samuel, M.D., 5 Somerset place.
805 Smart, William, M.A., LL.D., Professor of Political Economy, University of Glasgow, Nunholm, Dowanhill. 1886
Smellie, James, I.M., 112 Bath street. 1901
*a*Smith, Andrew, Miltonlea, Kilmalcolm. 1901
Smith, Colonel J. N., V.D., Dykebar house, Hawkhead, Paisley. 1900
Smith, D. Johnstone, C.A., 142 St Vincent street. 1888
810*a*Smith, David Baird, LL.B., 205 St Vincent street. 1903
*a*Smith, Fred. J., 40 St Vincent place. 1901
Smith, George, 1 Annfield terrace, East Partick. 1901
Smith, Hugh C., 55 Bath street. 1861
*a*Smith, J. Guthrie, 205 St Vincent street. 1875
815*a*Smith, James Murray, 11 Bute gardens. 1901
Smith, G. Comrie, 4 Camphill avenue, Langside. 1903
Smith, Patrick A., M.D., F.F.P.S.G., J.P., Dundrennan, 50 Queen Mary avenue, Crosshill. 1900
*a*Smith, Robert B., Bonnybridge, Stirlingshire. 1884
*a*Smith, W.B., 34 Buchanan street. 1895
820*a*Smith, W. Robertson, 8 Windsor terrace, W. 1902
Snodgrass, J. F., Ashbourne, Winton drive, Kelvinside. 1900
Snodgrass, William, M.A., M.B., C.M., F.F.P.S.G., 11 Victoria cres., Dowanhill. 1890
Soddy, Frederick, M.A., Chemistry Department, Glasgow University. 1904
*a*Somerville, Alex., B.Sc., F.L.S., 4 Bute mansions, Hillhead. 1888
825*a*Spencer, Charles L., Edgehill, Kelvinside. 1891
*a*Spencer, J. J., Edgehill, Kelvinside. 1895
Spens, John A., 169 West George street. 1879
*a*Steel, James, M.A., 502 St Vincent street. 1901
*a*Steel, William Strang, Philiphaugh, Selkirk. 1889
830*a*Stephen, John, Domira, Partick. 1880
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